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Design Factors and Functionality Matching in Sustainability Products: A study of eco-showerheads

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Abstract

The Demystifying the Shower Experience research project is a comprehensive multi-stage study aimed at understanding the multi-dimensional aspects of the shower, including; showering products, habits, behaviour and perceptions. The objective was to determine: if a functionality mismatch occurs between the design and desired functionality of the product, and what specific factors contribute to this mismatch. To achieve the aim, simple heuristic trials packaged as a *12 showerheads in 12 weeks Challenge* were conducted involving 12 participants – 6 male and 6 female. It was found that showerhead design factors such as colour, shape and size are inconclusive in determining the water efficient use, and perception of a positive shower experience. However, factors such as the number of function inform user choice and preference of which showerhead to choose and use. Further, sprout type and mode of operation both influence user perception of the performance factors such as feel, pleasantness, enjoyability, time taken and effectiveness of clean. And these factors in turn significantly affect the user perception of what constitutes a 'good' shower experience.

It was found that a functionality mismatch does occur in sustainability products if performance, and not design factors, fail to meet with user expectations. This work is novel because few, if any, studies of this nature have specifically been undertaken outside of the laboratory environment, and significant because the findings highlight the importance and influence of the physical design and performance-informing features on the user perception of the product itself. And for showerheads, this affects the satisfaction with the resulting showering experience and, therefore the propensity to use less water in the shower for an effective clean.

Keywords: Product performance, Product preferences, Sustainability products, User study, Water efficiency

1. Introduction

The efficient use of natural resources is top global political, social and economic agenda. The need to be resilient and assure the supply of essential natural resources such as water, has resulted in a myriad of strategies and solutions, including technological interventions, behaviour change campaigns, pricing regulations and other mechanisms, and in certain extreme cases, resource controls and rations which for water means drought orders and restrictions. In Australia for example, drought, coupled with growing populations enabled state and local government to implement alternative water supply schemes, along with a range of demand management interventions, in order to improve urban water security (Willis *et al.* 2013).

The need for innovative and intuitive consumer products to stimulate user behavioural responses in order to achieve the necessary improvements in water use is long established. After all, design, technological and engineering methods have the potential to mitigate wasteful practises during daily processes; e.g. washing of hands, and to assist in persuading or guiding users to operate products in a more sustainable manner, through self-management of resource consumption (Lockton *et al.* 2008). Studies conducted in the UK and US report that on average, applying water efficient designs and products leads to 15% less water use, 10-11% less energy use and 11-12% reduction in operating costs (Darby 2006; McGraw Hill report 2009). While engineering advances permit increased efficiency of product operation, the user's decisions and habits ultimately have a major effect on the water resources used by the product (Lockton *et al.* 2008).

The Demystifying the Shower Experience research project is a multi-stage study aimed at understanding the multi-dimensional aspects of resource use efficiency of *the shower*, and the practice of *taking a shower*. As Shove argues, social and cultural studies 'that set "the environment" aside as the main focus of attention' and instead study people's actual habits and expectations, and 'how new practices become normal' are both relevant and necessary (Shove, 2003, p. 9). Rather than evaluating the rise and fall of consumption as a means and end in and of itself, researchers have argued that we must focus on the socio-technical systems, practices and routines that enable consumption, and in which consumption is situated (Strengers 2011; Sofoulis, 2005; Warde, 2005). Sofoulis (2005) in particular stated that the idealist assumption of the 'environment-centred' approach is that water use practices will change simply by educating or persuading users about the value of water, as though they were ignorant of it. Hence, attaining sustainability goals will need more than campaigns to re-engineer user psychologies, or promote technological innovations that provide the same services with slightly less environmental damage. Change is therefore needed in all three dimensions of the co-evolutionary triangle: the socio-technical systems, the objects (water, and water technologies), and the habits and expectations of users.

The overarching aim is to contribute to further the demystification of physical and performance criteria that inform the user's expectation of 'a good shower' experience. Although some socio-psychological data will be considered as part of the study, this study excludes the study of behaviours and the impact of the technology to result in behaviour change. Learnings from previous studies were simply applied for the design and interpretation of this research findings. For example, previous studies on cognitive processes e.g. attitudes and habits, personal and social norms, rational choice etc. (Froehlich *et al.* 2010; Gregory and Leo 2003); psychological models of pro-environmental behaviours (Kollmuss and Agyeman 2002); studies to understand the role of user behaviours in resource use (E.g. Abrahamse *et al.* 2005) and; more aligned to this project, studies that show that physical and technical innovations in itself imply behaviour changes because individuals need to accept and understand them, buy them, and use them appropriately (Steg and Vlek 2009).

The project utilised the multi-methodological approach in various stages, combining empirical approach and experimental methods to understand user response to water-efficient showerhead products by documenting and modelling their physical, physiological and sociological needs and requirements. The objectives were:

1. To review and consolidate existing knowledge of design and performance requirements of a water efficient shower and the extent to which these affect the showering experience
2. To define the physical, physiological, sociological and performance metrics with which the showering activity can be defined and quantified
3. Using sampled participants, to examine differential preferences to the physical; design and performance factors of water efficient showerheads interpreted against the physiological and sociological needs of the user
4. To determine the extent to which the study methodology and the physical, physiological and sociological metrics applied can successfully define and potentially predict the user response to a type of water-efficient showerhead.

This paper addresses one of the non-empirical research question/hypothesis of the study (objective 3) i.e.: to what extent does the design features of the showerhead influence its perceived performance in aid of a good shower experience. Lending itself to what Corvellec (2016) refers to as the *performative definitions of sustainability objects*.

> To answer this question, a simple heuristic test was devised to compare the user's visual or visible preference for a water efficient showerhead to the experiential performance, thereby creating scope for comparative value. More importantly, the trials aimed to highlight the deterministic influence of the design and performing features in creating a cognitive bias i.e. a short-cut approach to decision-making which in turn affects the resultant perceived value of the product.

Further, the work explores the concept of functionality matching, or mismatch (Wever *et al.* 2008). A mismatch between delivered functionalities and desired functionalities is unsustainable twice. Redundant functionalities have an unnecessary impact, while missing functionalities can trigger unwanted behaviour, with subsequent unsustainable effects. Therefore, the outputs of this work aims to further progress existing knowledge on eliminating mismatches in sustainability products.

1.1 Why the Shower/showering?

Water use is a decision making process influenced by external affordances, personal attributes and attitudes amidst other sociological, economical and psychological factors. This disparity of purpose and influences creates the need for integrated models to simulate and explain the linkages between the factors that affect water use (Jorgensen *et al.* 2009). Systems of provision of water are now so well embedded in modern society that the infrastructure and the technologies that enable household consumption are largely taken for granted (Doron *et al.* 2011). However, the physical context is only one factor in defining overall water consumption, which should also be understood in its social and cultural context e.g. why are we using water to start with? (Shove 2005; Krantz 2005).

The study of shower and showering behaviour is increasingly important in demand-side water resource efficiency discourse. There is evidence that people in the UK in particular are showering more than ever before (EST 2013). Browne *et al.* (2014) highlighted showering as an effective example of the complexity of the emergence and maintenance of routines and habits, and how approaches to water efficiency that simply replace inefficient showering technology with water efficient technology fail to recognise the fairly recent emergence of showering as an established cleanliness practice. Showering is also an area in which new routines have far reaching environmental consequences; as it is now more common to shower once or sometimes twice a day. Power showers for example pump out between twenty and fifty litres a minute and with an average showering time of seven to eight minutes, water consumption soon exceeds that of a twice or thrice weekly bath (Hand, Shove and Southerton 2005).

Previous studies found that the use of efficient showerhead fixtures can result in significant reductions in the shower end use consumption (e.g. Inman and Jeffrey, 2006) without compromise on experience. Most 'water saver' showers achieve savings by introducing air or atomising the water drops to improve wetting for a given flow rate. The result feels like a 'power shower' but with perhaps 4-9 litres of water per minute rather than 12-20 litres (Gant 2006). This study tests the premise that a water efficient showerhead, irrespective of its design, does not compromise showering experience. More so as there have been very few studies that have specifically been undertaken to understand the influence of the physical properties (design and performance) of water-efficient or eco-showerheads on the user experience and satisfaction of the resulting showering experience. The only recent study found was by Okamoto *et al.* (2015), which utilised laboratory test apparatus to explore the influence of flow and spray on user satisfaction. The authors themselves cited previous laboratory-based studies, the latest of which was published in 2006, that explored the various design and performance characteristics of the showerhead using experimental scenarios.

2. Methodology

The field-based (quasi-naturalist) intervention methodology was utilised based on the repeated-measures design approach (Walker 2010). That is to intervene in a situation (naturalistic because the event will happen anyway), and to see what happens (Wood 2003; p 169). A survey and introduction workshop was held at the beginning of the study.

The experiment was structured in the form of a *12 showerheads in 12 weeks Challenge* with 12 participants taking part. There were 10 active eco-showerheads in the study and two 'dummy' ones for logistical reasons i.e. to ensure that all participants received one showerhead during each of the 12-week study period. The selected participants took turns to use each of the 12 showerheads for a week, completing a feedback sheet at the beginning and end of each study week (typically commencing on a Tuesday or Wednesday). Counter-balances were needed to minimise and check the potential fatigue effect and behaviour e.g. the two identical showerheads but with different colour combination and the two additional dummy showerheads. In addition, a post-study workshop was held after the 12-week period to further explore the trends identified in the feedback data. Following research ethics approval, the study was launched via group email and other marketing tools to the academic communities of two universities in a coastal city in South East England. The email contained a survey link for potential volunteers. Findings from this preliminary survey can be found in Adeyeye and She (2015).

A sample size of n = 12 consisting of 6 male and 6 female participants was selected from those that responded to the call. The resulting evaluation is based on the following:

- Demographics: equal number of male and female, age range for female participants 25-44 years, and for female 25 – 54 years.
- Anthropometrics: Height range for male participants 166-175cm (HSCIC 2013 measured mean range: 176.3 – 177.8cm, *standard mean 0.34, 0.3*), for female participants 151 – 171cm (HSCIC 2013 measured mean range: 162.8 – 163.3cm, *standard mean 0.32, 0.23*). Weight range for male participants 66 – 80kg (HSCIC 2013 measured mean range: 82.2 – 86.2kg, *standard mean 0.84, 0.78*), for female participants 51-60kg (HSCIC 2013 measured mean range: 70.2-73.8kg, *standard mean 0.78, 0.66*)

- Preference criteria aligned with design/lab-based metrics e.g. design: look/feel, flow, pressure, spray pattern and distribution etc.

Participants were asked to complete an initial feedback after the first use of the shower and then after last use at the end of week before receiving the next showerhead. 144 (12 feedback sheets per participants x 12 weeks) were expected but inevitably, some participant were on holiday during the study. Therefore, a total of 124 feedback datasheets were received from 12 participants. However, only 118 feedback data entries were used in analysis after nullifying incomplete feedback forms. The participants engaged in showering activities for an average of 1.48 times per day. Participants were asked to give feedback based on the Likert scale of 1 to 5; 1 = disagree and 5 = agree. The feedback were solicited in the form of 24 heuristic statements such as: I like the look of the showerhead; I like the coverage of the spray; I will be happy to continue to use this showerhead… etc. A sample of the feedback sheet can be found in Adeyeye and She (2015). Results are presented using mean values.

The showerheads utilised in the study are detailed in Table 1. Note that showerheads 07 and 10 are identical but of different colours, and that the showerheads included a range of shapes, spray types, functions (single/dual/multiple) to ensure the scope to test these criteria quantitatively in the laboratory and through user feedback. The study was conducted over a period of 12 weeks from the last week in April to mid-July. Therefore, it was not possible to document the seasonal impact of water use or the long-term impact. However, this has been covered in previous studies e.g. Lee *et al.* 2011. The participation incentive was the option to keep one of the showerheads at the end of the study.

Table 1: Attributes of the 10 sample showerheads

Ref No.	S-01	S-02	S-03	S-04	S-05	S-06	S-07	S-08	S-09	S-10
Shape	Round	Oblong	Round	Round	Round	Round	Round	Rectangle	Curved rectangle	Round
Height	90	157	106	100	100	106	135	67	65	135
Width	90	82	106	100	100	106	135	182	120	135
Height incl. handle	215	270	239	230	230	239	246	227	219	246
Construction	ABS plastic with grey hard plastic faceplate	ABS plastic with grey soft plastic faceplate	ABS plastic with grey hard plastic faceplate	ABS plastic	ABS plastic	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with white, hard plastic faceplate
Colour	Grey and chrome	Grey and chrome	Grey and chrome	Chrome	Chrome	Grey and chrome	Grey and chrome	Grey and chrome	Grey and chrome	White and chrome
Sprout Type	Recessed twin	Recessed twin	Recessed twin	Protruding single soft rubber	Protruding single soft rubber	Recessed twin	Recessed twin	Triple central, recessed twin	Recessed twin	Recessed twin
Sprout Layout	3 x 3 double sprout clusters	Two long double-sprout oval rows	Two concentric double sprout circles	Central core and radial rows	Central core and radial rows	3 x 3 double sprout clusters	Random x 3 clusters	Central triple clusters, random rows	Random	Random x 3 clusters
Inlet pipe connection (inch)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Working pressure (bar)	0.3 - 5.0	1.5 - 5.0	0.35 - 5.0	0.3 - 5.0	0.3 - 5.0	1.0 - 5.0	0.35 - 5.0	1.5 - 5.0	0.35 - 5.0	0.35 - 5.0
Measured Regulated flow rate @ 2 bar pressure	10.3	7.2	7.2	9.2	8.7	5.1	11.3	7.2	8.1	9.6
Regulated flow rate @ 2 bar pressure	8.7	8.7	7.9	13.2	12.9	5.1	7.6	7.4	8.3	7.6
Unregulated flow rate @ 2 bar pressure	14.5	14.5	23.9	N/A	N/A	N/A	23.3	13.8	21	23.3
Number of functions	1	4	1	3	1	1	2	2	1	2

Mode of operation	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	With Air	With Air	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets
Additional comments		Supplied with 9l/min flow regulator, Includes 1x vitamin C cartridge to neutralise chlorine	Supplied with 9l/min flow regulator	Rub clean nozzles	Rub clean nozzles	Supplied with 5.7l/min flow regulator fitted	Supplied with 9l/min flow regulator, Two types of spray - Satin jet body shower or massage	Ergonomic slider function selection on handle, Supplied with 9l/min flow regulator	Supplied with 9l/min flow regulator	Supplied with 9l/min flow regulator, Two types of spray - Satin jet body shower or massage
Image										

3. Results

It was postulated that both the design i.e. colour, shape, and size as well as the performance criteria i.e. flow, pressure of a showerhead product can influence user perception in terms of acceptability and experience during use. Both were examined here, the demographic and habitual influences are discussed elsewhere.

The data were analysed using SPSS and Sofa Stats software. All data presented are at 95% confidence intervals unless where stated otherwise. The mean and standard deviation values at the beginning and end of the trial week are shown in parentheses. There are multiple event data generated by each study participant as previously described. However, this paper presents on the analyses from the 2 x 12 feedback data per showerhead. Over a trial week for each showerhead, each participant provided a first feedback on the showerhead at the start of the week (preferably after the first shower event), and a second, at the end of the week. A limitation is that, inevitably, some participants were away during one or two trial weeks in the study period which further impacted on the data gathered. For data visualisation, boxplot diagrams showing comparative feedback data were preferred. This helped to better highlight the degree of spread in the feedback data, as well as the degree of change in perception during the trial week. This is always an important consideration for decisions that are based on this and similar studies in the future.

For consistency, following notations applies to all discussions unless otherwise stated:

R: Responses, 5 = agree; 3 = neutral; 1 = disagree;
n: number of valid samples collected;
$\bar{R}_{pre}$ and σ_{pre}: mean and standard deviations of samples collected at start of trial week;
$\bar{R}_{post}$ and σ_{post}: mean and standard deviations of samples collected at end of trial week;

3.1 Design as influencing factor

This section builds on studies (e.g. Page 2014) which found that appearance and reliability exerted considerable influence on participants' decisions to replace products.

Colour: Figure 1 is a boxplot of responses to the exploration of the appearance preferences of the showerheads. It was found that colour does inform choice or preference of a showerhead but not to a significant degree (Figure 1). Majority of the participants indicated higher preference for the grey and chrome showerheads (n = 67, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.64 / 3.72, $\sigma_{pre}/\sigma_{post}$ = 1.083 /1.027). 6 of the showerheads in the study sample were of this colour (hence n= 67). A slight shift in preference from neutral to strongly agree at the end of this week was also noted for the mainly chrome showerheads (n = 21, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.81 / 3.86, $\sigma_{pre}/\sigma_{post}$ = 1.078 /.964), and for the white and chrome (n = 12, $\bar{R}_{pre}/\bar{R}_{post}$ = 4.33 / 4.33, $\sigma_{pre}/\sigma_{post}$ = 0.6513 /0.492 at 95% confidence intervals); the latter expressing a very strong interest for this showerhead. Also, majority indicated that they would be happy to buy or keep the combined Grey and Chrome showerheads respectively. No significant comparative change in preference was noted at the beginning or end of the week. Nor any significant correlation based on gender found to influence the preference; approximately equal number of male and female participants indicated a preference for the grey and chrome showerheads.

Figure 1: Showerhead appearance (colour) preference and both feedback stages during the trial week.

Shape: On the shape of the showerheads, majority of the participants (n= 70, $\bar{R}_{pre}/\bar{R}_{post} =$ 3.84/3.87, $\sigma_{pre}/\sigma_{post}$ = 0.947/0.851) also preferred the round showerheads (6 of the 12 showerheads in the sample). Again, although not statistically significant, 41 and 29 of the 70 data responses were male and female respondents respectively. 22% ($\bar{R}_{pre}/\bar{R}_{post}$ = 3.86/3.82, $\sigma_{pre}/\sigma_{post}$ 1.167/1.296) preferred the rectangular showerheads and only 11% ($\bar{R}_{pre}/\bar{R}_{post}$ = 3.09/3.55, $\sigma_{pre}/\sigma_{post}$= 1.3 /1.036) stated that they preferred the oblong showerhead. The same majority of 70% stated that they would be happy to buy and keep the showerheads at the beginning of the week but this changed to 67% respectively at the end of the week.

Figure 2: Showerhead appearance (shape) preference and both feedback stages during the trial week

Shower material: Material was explored against how the users perceived the physical feel and handling of the showerhead. All the showerheads were made with Acrylonitrile butadiene styrene (ABS), a type of thermoplastic commonly used for plumbing and mechanical products. However, Showerhead S-02 is made of ABS plastic with grey soft plastic faceplate, Showerheads S-01, 03, 08 and 09 with grey, hard plastic faceplates, S-10 with white, hard plastic faceplate and S-04 and 05 are simply chrome-plated (due to space constraints, please consult Table 1 for shower data and images).

Figure 3: Comparative feedback on the physical feel of each showerhead

Majority of the participants (n = 100, 46% pre-trial and 37% post trial) were mostly indifferent/ neutral to the physical/material feel of the showerhead. However, for the first time, change in perception were noted for most of the showerheads in the feedback from the beginning and end of the trial period (Figure 3). Of note was the response to the physical feel of showerheads S-01, 06 and 09 which generated a negative perception at the end of the trial week. This raises a curious point about why this occurred and the answer which is more related to the performance of the showerhead, than the feel occurs in subsequent sections and in the discussion of the comments. Perceptions about the general feel of showerheads S-04, 05, 07, 08 and 10 also improved during the week with most participants responding to the additional weight (mostly due to size) of S-07, 08 and 10.

Size and sprout layout: The design factors: size and sprout layout of each showerhead were explored in relation of the perceived coverage and effort necessary to achieve a 'good clean'. The general preference was for standard sized showerheads (n = 68, compared to n=31 for the large sized (S- 07, 08 and 10). However, the larger sized showerheads (ø 135mm) were considered to deliver better spray coverage compared to the standard sized ones (Figure 4). The mean differences at the beginning and end of the trial week were not significant (for large showerheads $\bar{R}_{pre}/\bar{R}_{post}$ = 3.61/3.74, $\sigma_{pre}/\sigma_{post}$ = 1.26/ 1.44, standard showerheads $\bar{R}_{pre}/\bar{R}_{post}$ = 3.38/3.44, $\sigma_{pre}/\sigma_{post}$= 1.21/

1.24). Here again, the previously mentioned outliers S-01, 03 and 06 were consistently given the lowest rating at the beginning and end of the trial week by all participant.

Figure 4: Comparative feedback on showerhead size relative to the spray coverage

The perceived performance for the amount of time and effort to get clean was however less than average for all types of showerheads (*for large showerheads* $\bar{R}_{pre}/\bar{R}_{post}$ = 2.74/2.9, $\sigma_{pre}/\sigma_{post}$ = 1.00/1.01, *for standard showerheads* $\bar{R}_{pre}/\bar{R}_{post}$ = 2.59/2.43, $\sigma_{pre}/\sigma_{post}$= 0.90/1.03). This will be discussed in the context of flow rates later. The spread of the data indicates the lack of overwhelming consensus. Also worthy of note is the negative moving trend in the feedback at the end of the trial week. Also interesting are the outliers: S-04 and 07/10 at the beginning of the week and, S-06 at the end of the week. Exploring the data further, it was found that the higher preference especially post trial week for showerheads like S-04 were mostly women, whilst for S-06 were mostly men. This preference by women will be further highlighted in comments made regarding to the amount of water and coverage needed for activities such as washing of hair. One or two (with shower over bath arrangements) also complained that the larger showerheads where too big and they ended up with most of the water on the floor rather than on their body.

Figure 5: Influence of showerhead sized on perceived time it took to achieve an effective clean.

Figure 6a & b: Mean plot of influence of sprout layout on perceived time to clean and spray coverage

The sprout layouts for the sample showerheads consisted of S-01 and S-06 with 3 x 3 double sprout clusters, S-02 with two long double-sprout oval rows, S-03 with two concentric double sprout circles, S-04 and S-05 with Central core and radial rows, S-07 and S-10 has Random x 3 clusters, and S-09 has fully random layout. The lack of distinct consensus is clear (figure 6a&b), as is expected in instances of multiple variables but the low preference for S-01 and S-06 with the 3x3 double sprouts is again apparent. There was again less than average means for the time and effort taken to achieve a 'good clean' for all types of sprout layouts with the two long double-sprout oval rows (S-02, n= 11, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.27/1.72, $\sigma_{pre}/\sigma_{post}$ = 0.91/1.01) being the least favoured especially post trial week, followed closely by 3x3 double sprouts (S-01 and S-03, n= 18, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.67/2.44, $\sigma_{pre}/\sigma_{post}$ = 1.09/1.34, *note skewness and kurtosis in Table 2*).

Table 2a: Descriptive data for showerhead sprout layouts in terms of coverage

SHOWERHEAD_SPROUT LAYOUT				Statistic	Std. Error
PRE_SPRAYCOVERAGE	3 x 3 double sprout clusters	Mean		3.00	0.36
		95% Confidence Interval for Mean	Lower Bound	2.24	
			Upper Bound	3.76	
		Std. Deviation		1.53	
		Skewness		-0.22	0.54
		Kurtosis		-1.55	1.04
	Central core and radial rows	Mean		3.64	0.21
		95% Confidence Interval for Mean	Lower Bound	3.20	
			Upper Bound	4.07	
		Std. Deviation		1.22	
		Skewness		-0.67	0.41
		Kurtosis		-0.50	0.80
	Random	Mean		3.20	0.39
		95% Confidence Interval for Mean	Lower Bound	2.32	
			Upper Bound	4.08	
		Std. Deviation		1.23	
		Skewness		0.43	0.69
		Kurtosis		-1.46	1.33
	Random x 3 clusters	Mean		3.79	0.25
		95% Confidence Interval for Mean	Lower Bound	3.27	
			Upper Bound	4.31	
		Std. Deviation		1.08	
		Skewness		-0.41	0.52
		Kurtosis		-1.03	1.01
	Two concentric double sprout circles	Mean		3.38	0.42
		95% Confidence Interval for Mean	Lower Bound	2.38	

SHOWERHEAD_SPROUT LAYOUT				Statistic	Std. Error
POST_SPRAYCOVERAGE	3 x 3 double sprout clusters	Mean		2.83	0.36
		95% Confidence Interval for Mean	Lower Bound	2.07	
			Upper Bound	3.60	
		Std. Deviation		1.54	
		Skewness		-0.01	0.54
		Kurtosis		-1.52	1.04
	Central core and radial rows	Mean		3.70	0.24
		95% Confidence Interval for Mean	Lower Bound	3.21	
			Upper Bound	4.19	
		Std. Deviation		1.38	
		Skewness		-0.70	0.41
		Kurtosis		-0.82	0.80
	Random	Mean		3.40	0.31
		95% Confidence Interval for Mean	Lower Bound	2.71	
			Upper Bound	4.09	
		Std. Deviation		0.97	
		Skewness		0.81	0.69
		Kurtosis		-0.02	1.33
	Random x 3 clusters	Mean		4.00	0.25
		95% Confidence Interval for Mean	Lower Bound	3.47	
			Upper Bound	4.53	
		Std. Deviation		1.11	
		Skewness		-0.83	0.52
		Kurtosis		-0.56	1.01
	Two concentric double sprout circles	Mean		3.50	0.42
		95% Confidence Interval for Mean	Lower Bound	2.50	

			Upper Bound	4.37					Upper Bound	4.50	
		Std. Deviation		1.19				Std. Deviation		1.20	
		Skewness		-0.97	0.75			Skewness		-1.34	0.75
		Kurtosis		1.87	1.48			Kurtosis		2.58	1.48
	Two long double-sprout oval rows	Mean		3.36	0.24		Two long double-sprout oval rows	Mean		3.55	0.31
		95% Confidence Interval for Mean	Lower Bound	2.82				95% Confidence Interval for Mean	Lower Bound	2.85	
		Std. Deviation		0.81				Std. Deviation		1.04	
		Skewness		0.54	0.66			Skewness		0.51	0.66
		Kurtosis		0.64	1.28			Kurtosis		-1.03	1.28

Table 2b: Descriptive data for showerhead sprout layouts showing perception on the effort to clean

SHOWERHEAD_SPROUT LAYOUT				Statistic	Std. Error	SHOWERHEAD_SPROUT LAYOUT				Statistic	Std. Error
PRE_TIME/EFFORT TO CLEAN	3 x 3 double sprout clusters	Mean		2.67	0.26	POST_TIME/EFFORT TO CLEAN	3 x 3 double sprout clusters	Mean		2.44	0.32
		95% Confidence Interval for Mean	Lower Bound	2.13				95% Confidence Interval for Mean	Lower Bound	1.78	
			Upper Bound	3.21					Upper Bound	3.11	
		Std. Deviation		1.08				Std. Deviation		1.34	
		Skewness		-0.17	0.54			Skewness		0.38	0.54
		Kurtosis		-1.19	1.04			Kurtosis		-1.19	1.04
	Central core and radial rows	Mean		2.79	0.14		Central core and radial rows	Mean		2.97	0.15
		95% Confidence Interval for Mean	Lower Bound	2.50				95% Confidence Interval for Mean	Lower Bound	2.66	
			Upper Bound	3.08					Upper Bound	3.28	
		Std. Deviation		0.82				Std. Deviation		0.88	
		Skewness		0.06	0.41			Skewness		-0.23	0.41
		Kurtosis		1.20	0.80			Kurtosis		0.43	0.80
	Random	Mean		2.70	0.21		Random	Mean		2.40	0.22
		95% Confidence Interval for Mean	Lower Bound	2.22				95% Confidence	Lower Bound	1.90	

			Upper Bound	3.18				Interval for Mean	Upper Bound	2.90	
		Std. Deviation		0.67				Std. Deviation		0.70	
		Skewness		0.43	0.69			Skewness		-0.78	0.69
		Kurtosis		-0.28	1.33			Kurtosis		-0.15	1.33
	Random x 3 clusters	Mean		2.70	0.28		Random x 3 clusters	Mean		2.80	0.25
		95% Confidence Interval for Mean	Lower Bound	2.11				95% Confidence Interval for Mean	Lower Bound	2.28	
			Upper Bound	3.29					Upper Bound	3.32	
		Std. Deviation		1.26				Std. Deviation		1.11	
		Skewness		0.28	0.51			Skewness		0.44	0.51
		Kurtosis		-0.70	0.99			Kurtosis		0.07	0.99
	Two concentric double sprout circles	Mean		2.50	0.27		Two concentric double sprout circles	Mean		2.38	0.26
		95% Confidence Interval for Mean	Lower Bound	1.87				95% Confidence Interval for Mean	Lower Bound	1.75	
			Upper Bound	3.13					Upper Bound	3.00	
		Std. Deviation		0.76				Std. Deviation		0.74	
		Skewness		-1.32	0.75			Skewness		-0.82	0.75
		Kurtosis		0.88	1.48			Kurtosis		-0.15	1.48
	Two long double-sprout oval rows	Mean		2.27	0.27		Two long double-sprout oval rows	Mean		1.73	0.30
		95% Confidence Interval for Mean	Lower Bound	1.67				95% Confidence Interval for Mean	Lower Bound	1.05	
			Upper Bound	2.88					Upper Bound	2.41	
		Std. Deviation		0.90				Std. Deviation		1.01	
		Skewness		0.34	0.66			Skewness		1.37	0.66
		Kurtosis		-0.05	1.28			Kurtosis		1.32	1.28

3.2 Performance as influencing factor

Pressure: The participants were asked to feedback on the working pressure of each of the sample showerheads. Two criteria were used to gauge user perception of pressure – pleasant pressure on the body, and consistent pressure on the body. The working pressure of the sample showers were broadly in 2 ranges; 1.0 – 5.0 bars for S-02, 06 and 08 with only shower S-06 operating at the low 1bar range, and 0.3 – 5.0 bar for the remaining showerheads.

The results (Figure 7) shows that most of the participants considered – as best as is perceivable without actual quantifiable evidence - that the showerheads delivered a consistent water pressure. This stays the same or fell slightly at the end of the trial week with the exception of S-02 (n = 11, $\bar{R}_{pre}/\bar{R}_{post}$ = 4.09/4.55, $\sigma_{pre}/\sigma_{post}$ = 0.83/0.82). S-06 also consistently received lower mean values (n = 9, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.22/3.44, $\sigma_{pre}/\sigma_{post}$=1.563/1.509). Both S-02 and S-06 operate at similar working pressure rates of 1.5 and 1.0- 5 bar respectively. Both showerheads use double sprouts to deliver colliding twin jets that turn into thousands of tiny droplets. The difference is the number of sprouts – S-06 has only 9 sets of sprouts, and the amount of water delivered – 9l/min flow regulator for the S-02 compared to the 5.7l/min flow regulator fitted to S-06. This finding confirms that design factors such as this can influence user perception of the performance factors such as water pressure.

Figure 7: Mean plot of perceived consistency and pleasant feel of pressure at the beginning and end of the trial week per showerhead

However, the pleasant feel of the pressure for most of the showerheads were less favourable with the exception of S-07 (n = 8, $\bar{R}_{pre}/\bar{R}_{post}$ = 4.13/3.88, $\sigma_{pre}/\sigma_{post}$ = 0.64/0.64) and S-10 (n=12, $\bar{R}_{pre}/\bar{R}_{post}$ = 4.08/4.08, $\sigma_{pre}/\sigma_{post}$ = 0.67/0.67). This also appears to support the previous assumptive statement of the amount of water delivered to the body being analogous to perceptions of pressure. The result that women ($\bar{R}_{post}$ = 3.62, σ_{post} 1.168 @ 95% confidence interval) rated the pleasantness of the pressure slightly less than the male counterparts ($\bar{R}_{post}$ = 3.397, σ_{post} 1.225) post trial week is not statistically significant (p = 0.318).

Mode of water delivery: Perceptive factors assessed here were the feel of spray on the body, consistent temperature and acoustics/sound of the shower. There were two modes of operation in the showerhead sample – water delivered mixed *with Air*, and water delivered as *colliding twin jets that turn into thousands of tiny droplets*. Figure 8 shows that with the exception of S=06, the feedback displayed only a slight mean difference between the two modes of delivery; colliding jets (n = 79, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.63/3.54, $\sigma_{pre}/\sigma_{post}$ = 1.113/ 1.228) and with air (n= 21, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.81/3.71, $\sigma_{pre}/\sigma_{post}$ = 0.87/.96) with a rising spread for the colliding twin jets towards the end of the trial week.

Figure 8: Shower mode versus perceived spray feel, as perceived at the beginning and end of the shower trial week.

Breaking this down further (Figure 9), it was found that there were mixed responses for both shower modes. This suggests that the mode of delivering the shower spray is again not an important criteria. Although, S-01 (n = 9, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.0/2.78, $\sigma_{pre}/\sigma_{post}$ = 1.414/1.481) and S-06 (n = 9, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.22/3.11, $\sigma_{pre}/\sigma_{post}$ = 1.79/1.69) performed the least favourably. Both showers had the least number of twin sprouts i.e. 9. The difference in the preference between the male and female participants is also apparent. The reasons for this became more apparent in the feedback comments and during the post-trial workshop; both are presented later.

Figure 9: Shower mode versus perceived spray feel, as perceived at the beginning and end of the shower trial week.

Feedback was obtained on the effect of the shower mode on the temperature distribution on the body and the shower acoustics. The mean results for temperature for colliding jets were: n= 79, $\bar{R}_{pre}/\bar{R}_{post}$ = 4.06/3.99, $\sigma_{pre}/\sigma_{post}$ = 1.11/1.12, and with Air: n = 21, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.06/ 3.99, $\sigma_{pre}/\sigma_{post}$ = 0.92/ 0.79. The average results for sound for colliding jets were: n= 79, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.87/3.73, $\sigma_{pre}/\sigma_{post}$ = 0.97/1.00, and with Air: n = 21, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.62/ 3.67, $\sigma_{pre}/\sigma_{post}$ = 0.87/ 1.07. There was a significant spread for the responses and again, the main outliers for poor performance were S-01 and 06 with the colliding jets showers so the response for each showerhead was required (Figure 10). This chart again shows the comparatively low results for S-01 and 06 and the comments and discussion will shed more light on this. Better performing were S-02, 07 and 10. S-07 and 10 are the larger showerheads so it is more beneficial to explore S-02 further.

Figure 10: Shower mode and perceived temperature and acoustics characteristics.

Number of functions: S-01, 03, 05, 06 and 09 only had only one shower function. Both S-07 and 10 have two - shower and massage functions. S-04 (ø 100mm) has 3 functions; shower, shower + air, massage. S-02, the better performing showerhead in the previous section is the most expensive of the sample showerheads. This is because in addition to the other design and performance characteristics specified in Table 1, it also has a Vitamin C filter to de-chlorinate the water, 4 separate functions (3 spray patterns) and a swivel head (which only one of the participants figured out as no instructions were given). This section compares the impact of single and multiple function showerheads on experiential feedback such as enjoy-ability and frequency of use.

When asked if the functions improved the enjoy-ability of the showering experience, the feedback was as follows: Single function (n = 47, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.49/3.15, $\sigma_{pre}/\sigma_{post}$ = 1.12/1.197), Dual function (n = 32, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.87/3.91, $\sigma_{pre}/\sigma_{post}$= 0.79/1.03), Triple function (n = 10, $\bar{R}_{pre}/\bar{R}_{post}$= 3.4/4.1, $\sigma_{pre}/\sigma_{post}$= 0.79/1.00), and Quadruple function (n = 11, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.64/3.73, $\sigma_{pre}/\sigma_{post}$ = 0.81/0.95). In general, the multifunction showerheads received better feedback compared to the single function ones. S-01 and S-06 received comparatively lower feedback for single function showers, whilst S-08 and S-10 received the most polarised feedback.

Figure 11a&b: Shower function and influence on enjoyability and frequency of use

The optimum number of functions appear to be between 2 and 3 (Figure 11) but again these results are quite marginal and further studies are required for validation.

Figure 12: Shower mode and perceived temperature and acoustics characteristics.

With a few exceptions, the participants stated that the number of functions did not translate to having more showers. Only S-07 returned an anomalous above average response, not confirmed by the identical S-10.

Sprout type and flow rate: The regulated flow rates measured at 2 bar for each showerhead is shown in Table 1. The flow rates indicate measurements for the standard shower setting for all the showerheads; water use for other settings in multi-function showers will vary. This section reviews the extent to which the sprout type and flow rate (litres/minute) dispensed from each showerhead influenced (a) the extent to this users enjoyed the shower, (b) the required cleaning effort (c) the duration of the shower, and by inference the amount of water consumed, (d) willingness to keep the showerhead post the study (*participant incentive was a free showerhead at the end of the study*).

Table 3: Feedback results correlated with flow rates and the showerheads groups according to sprout types

Flow rate (L/min)	Shower Head No	Sprout type		PRE_LOWEFFORT TO CLEAN	POST_LOW EFFORT TO CLEAN	AVE_DURATION (mins)	PRE_WILL KEEP	POST_WILL KEEP	PRE_ENJOYABLE USE	POST_ENJOYABLE USE
5 – 6.9	**S-06**	recessed twin	Mean	2.67	2.78	11.80	2.44	2.00	3.33	3.00
			N	9.00	9.00	9.00	9.00	9.00	9.00	9.00
			Std. Dev.	1.41	1.72	8.96	1.59	1.32	1.80	1.66
7 - 9	**S-01, 02, 03, 07, 09, 10**	recessed twin	Mean	2.56	2.36	11.41	2.78	2.70	3.64	3.60
			N	59.00	58.00	59.00	59.00	57.00	59.00	58.00
			Std. Dev.	0.97	0.99	12.55	1.37	1.45	0.89	1.06
	S-08	triple central, recessed twin	Mean	3.00	3.25	12.76	2.83	3.17	3.67	3.75
			N	12.00	12.00	12.00	12.00	12.00	12.00	12.00
			Std. Dev.	0.60	0.97	9.88	1.59	1.85	0.78	1.22
> 9	**S-04, 05**	protruding single soft rubber	Mean	2.65	2.81	11.42	3.35	2.90	3.83	3.52
			N	23.00	21.00	23.00	23.00	21.00	23.00	21.00
			Std. Dev.	0.88	0.81	9.41	1.07	1.34	0.78	1.12

Participants rated the single function S-04 (triple function, with air) and 05 (ø100mm, round, chrome, single function, with Air) both with the protruding single soft rubber sprouts the more enjoyable showerheads to use (n=21, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.86/3.52, $\sigma_{pre}/\sigma_{post}$ = 0.80/1.12). Next was S-08 (67 x182mm, rectangular, double function, colliding jets) with triple central, recessed twin sprouts (n = 12, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.67/ 3.75, $\sigma_{pre}/\sigma_{post}$ = 0.78/1.22). Marginally behind were the showerheads with the recessed twin sprouts (n = 67, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.58/ 3.52, $\sigma_{pre}/\sigma_{post}$ = 1/05/1.16) that delivered colliding twin jets that turn into thousands of tiny droplets (Table 3). The recurring outliers on the lower range were again S-01 and 06. It is worth noting that all the favoured showerheads has more number of sprouts compared to the others. Also, these showerheads tend to be on the higher flow rate spectrum although all the showerheads had flow regulators to the required efficiency benchmarks.

Conversely, participants on average rated the triple central, recessed twin sprout showerhead S-08 marginally higher than the average threshold, compared to the other two. This was followed by the showerheads with the protruding sprouts S-04 and 05. These two higher flow showerheads also received marginally higher feedback on the interest to keep beyond the study. The average shower duration for all types of sprouts were over 11minutes. It is therefore inferred that the flow rate, sprout type and mode of water deliver impacted significantly on the time spent in the shower. This and other related findings are discussed in more detail in another paper.

Other findings: Other interesting findings were that even though the showerheads with the protruding single sprouts that delivered water mixed with Air were found to deliver the most enjoyable shower. On average, the participants rated them the least pleasant on the acoustic range with more than one participant considering them to be 'quite noisy'. Also, the participants were also asked if the mode of delivery affected the amount of effort it took to 'get clean'. Majority disagreed; for colliding jets showerheads (n=80, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.64/2.54, $\sigma_{pre}/\sigma_{post}$ = 0.98/1.12) and with Air (n = 23, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.65/ 2.81, $\sigma_{pre}/\sigma_{post}$ = 0.89/ 0.81). The same results were given for the size of the showerheads; Large (n = 32, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.81/2.97, $\sigma_{pre}/\sigma_{post}$ = 1.07/1.06) and Standard (n=71, $\bar{R}_{pre}/\bar{R}_{post}$ = 2.56/2.43, $\sigma_{pre}/\sigma_{post}$ = 0.91/1.03). Similar results were received for the Sprout Type and Layout with the exception of S-08, the only showerhead with; long rectangular shape, the triple central, recessed twin sprout type and Central triple clusters, random rows (n = 12, $\bar{R}_{pre}/\bar{R}_{post}$ = 3.00/3.25, $\sigma_{pre}/\sigma_{post}$ = 0.60/0.97).

3.3 Participants' general comments and feedback

Comment excerpts for each showerhead given at the beginning and end of each trial week are summarised in Table 4.

Table 4: Additional user comments

Showerhead No	Feedback	
	Beginning of trial week	**End of trial week**
S-01	• I like the strong pressure • The spray was too fine, stingy and sort of spat everywhere	• The showerhead kept moving and I had to keep readjusting it • Took longer to wash. The spray is too thin and it took forever to wash with this showerhead. And it doesn't rinse off conditioner properly so I am spending a long time trying to rinse my hair and it is still sticky when I come out of the shower :(
S-02	• I like this showerhead, though it doesn't not have 4 spray settings, which is my favourite! • I liked the showerhead, but I thought the 4 spray patterns were a bit over-complicated. I only liked the spray pattern that used all the holes/sprays • This showerhead poured water outside of the shower partition so I had to hold it in order to use it and not cause a flood in the bathroom	• At first I liked this showerhead, but over the week I found it annoying as I had to move to find the best way to rinse my hair
S-03	• This has one basic spray setting which now that I have had a multi-functional showerhead feels lacking • The No 3 is fine but doesn't have any advanced functionality so it appears to be an austerity showerhead	
S-04	• This is my favourite so far - I like the size and shape of the showerhead and the variety of the flow settings	• I prefer a strong spray, but this is much better than the others • Favourite so far! Really liked the two spray positions and the size and shape of the showerhead
S-05	• No force behind the spray • A stronger pressure. It feels more concentrated so I am not wasting water • This shower is noisy	• No force behind the spray • Although I prefer a harder shower with a concentrated option, this was the closest I got to feeling pressure in the 'spray' mode

		• Had to remove showerhead as it covered the bathroom floor with water
S-06	• I really don't like the spray pattern/ feel	• Least favourite showerhead so far! • This is my least favourite showerhead so far. I have to hold the showerhead really close to my head to rinse off the conditioner as the water is too fine to be effective • Favourite so far! • Very low pressure i.e. a mist
S-07	• I enjoyed the central spray feature, and the coverage was ace • It seems too big a showerhead for my space	• My favourite showerhead so far! And I liked the choice of spray • I was pleased with this showerhead • The head is too big and keeps changing position as it is too heavy. I had to move right back as far as I could to use it
S-08	• Whilst I quite liked the showerhead, the head was a strange shape which meant that the spray went more to the sides (including outside the bath) and less on me! • I felt like I was standing in rain, it was nice	• I would like this showerhead better if I have a large enclosed shower cubicle. But in a small bathroom with shower over bath, this showerhead sprayed water all over my bathroom floor especially when washing my hair • Best one yet • Showerhead left water all over my bathroom floor • I had to change the angle of the showerhead holder to stop it spraying out of the bath on to the floor, but once I had done this I started to enjoy using this showerhead. (My partner thought that the showerhead was too big and cumbersome though)
S-09	• It is a gentle spray and feels a bit lighter than my normal showerhead but I liked it	• Generally, great showerhead though I missed the variation in spray switch that some of them had • I like the size better, but the pressure is too weak. It takes longer to rinse my long hair
S-10	• I could not get a hot shower!! Only warm??	• Too light pressure • The shower would not dispense hot water • Definitely my favourite showerhead so far. I like that it has a middle setting which allows full coverage but reduces the bounce-off/spraying so I can keep water within my bath

A post-study workshop was held at the end of the 3-month trial period to further explore the key findings of the study. 8 of the 12 study participants (5 male, 3 female) attended the post-study workshop. The relevant feedback are summarised below:

- Showerheads should be designed considering the extreme ranges of water pressure, and plumbing systems e.g. combi boiler versus hot water tanks
- Showerheads should have a solid, weighty 'feel' to it. Some perceived that the lightness of the materials suggested that it was cheap or cheaply made
- Crossing sprays e.g. shower S-06 is not particularly liked
- Majority preferred the round showerhead but the participants do not particularly care about the design of the showerheads. They are more focussed on the performance i.e. 'how effective is the spray'.
- There appeared to be a general perception that the quality of the spray is affected by the shape of the showerheads
- Non-explicit design features in showerheads are often missed e.g. only 1 participant realised that the head of shower 2 could be rotated

- Multi-functional showerheads are preferred at least until a choice of spray type/mode is decided. Then majority of the male participants stated that they are more likely to stick with the one mode once a choice is made. The women stated that they may still vary e.g. for washing hair versus every day shower.
- Majority stated that 5 minutes is not long enough to get a decent clean especially when washing hair and seasonal factors should be considered
- On average, all participants liked showerheads 04, 07/10 and 08 because they were: Multi-functional; Feel (heavy); Spray coverage; Good spray pattern; Appears water efficient
- On average, all participants did not like showerheads 01, 06 because of the following reasons:
    - Poor feel, looks cheap
    - Poor coverage
    - Poor spray pattern
    - Number of holes, sprouts suggests that performance will be reduced if they are blocked with lime scale
    - Single function equals no choice

5. Discussion

The aim of the work presented in this paper was to determine the factorial influence of eco showerhead's physical and performance characteristics for informing the user perception of a good shower. The purpose was to ask users to participate in a simple heuristic test to compare the user's visual and experiential performance preference for sampled showerheads. And the study output contributed to determining the higher valued design and performance characteristics which influenced water use efficiency in the shower with the least impact on their showering experience.

It was found that design factors such as colour and shape of the showerhead does not significantly influence water use, nor inform perception of a good shower experience. It was noted that most participants accepted round and chrome showerheads as this was considered to be norm. But nonetheless indicated higher preference for a mixture of chrome and grey coloured showerheads, and some preferred the rectangular showerheads to the round ones. The feel of the material was also considered acceptable with one or two comments on the plastic feel of some of the showerheads appearing to imply cheaply made. The same applied to size of the showerhead which was also not considered to inform any significant design choice. However, the size of the showerhead was considered to be important in terms of the coverage of the spray and effectiveness of clean, and in this context, preference was given to the larger showerheads. However, no significant correlation was found between the size of the showerhead and the duration of the shower.

It was found that the performance-informing features such as the sprout type, mode, number of functions etc. significantly influenced the perception of a good shower experience. It was also found that these factors influenced more tangible performance factors such as the perception of the volume of water delivered and the perceived pressure on the body. These also affected subjective factors such as the pleasantness of the feel and enjoyability of the shower experience.

Other notable findings were that the optimum number of functions appear to be between 2 and 3 as participants would prefer to have a choice, but too many functions i.e. 4 or more were not considered necessary. Showers with too fine a spray e.g. S-01 and S-06, and less number of sprouts received comparatively less favourable feedback. Also, it was noticed that once participants expressed a disfavour to these showerheads, they consistently gave them low feedback on almost all of the evaluated criteria. It was also found that identical showerheads S-07 and S-10 did not always received near-identical feedback. It is in this instances that factors such as preference for colour (white and grey face, chrome body) could have played a factor. But further studies are required to confirm this.

Based on the criteria considered in this paper, showerhead S-08 appeared to have the highest overall rating amongst the 10 showerheads included in the study. This showerhead is rectangular 182 x 67cm in size, it has 2 function selected with an ergonomic slider, and it has a chrome body with grey faceplate. It has many twin recessed sprouts in triple clusters. The sprouts are delivered in random rows. The showerhead delivers a regulated 7-9 litres per minute (depending on plumbing set-up) via colliding jets of water that turn into tiny droplets. Closely following S08 were showerheads S-04 and S-05, the only two showerheads that delivers water mixed with air. These showerheads again have many single protruding, and rub clean nozzles in a central core and radial rows layout. This sprout type and mode of operation requires a significant higher operating water pressure (Table 1) compared to the other showerheads. However, the acoustic level of S-05 was considered high, and the feel too strong by some of the participants.

The cumulative finding is that showerhead design factors such as colour, shape and size are inconclusive in determining the water efficient use, and perception of a positive shower experience. However, factors such as the number of function inform user choice and preference of which showerhead to choose and use. Further, sprout type and mode of operation both influence user perception of the performance factors such as feel, pleasantness, enjoyability, time taken and effectiveness of clean etc. Factors that in turn significantly affect the user perception of what constitutes a 'good' shower experience. However, a scaled-up study with more participants is needed to fully ratify these findings.

All the participants at the post-study workshop confirmed that their water use efficiency improved during and beyond the study. They said that they are more positive about saving water and spending less time in the shower. They also confirmed that their general understanding of, and perception towards showering, and water used during this activity is much improved. This further shows that socio-technical studies of this nature has the potential to deliver results such as raised awareness and encouraging behaviour change, beyond the initial objectives of the study.

6. Conclusion

The eco-showerhead as a sustainable product entity serves as a direct means to achieve sustainable water use efficiency i.e. it outputs less water per minute compared to its non-sustainable counterpart. It achieves these through its design and its performance. All the user needs to do in response is to (1) make the active choice to purchase and use the product (2) use the resource and product correctly, and external to the product's function (3) change behaviours and habits relative to the use of the product. A significant body of research exists on each one of those points, particularly on user attitudes, habits and behaviours. It is also notable that studies on sustainable consumption tends to focus largely on purchasing behaviours and not on its actual use (Bhamra, Lilley & Tang 2015). However, this work argues for a more robust approach to the study of these dimensions of the co-evolutionary triangle: the socio-technical systems, the objects (water, and water technologies), and the habits and expectations of users.

The study of this tripartite interaction was framed and explored in the context of what Wever *et al.* (2008) refers to as functionality matching i.e. the match or mismatch between desired functionalities and delivered functionalities. Functionality mismatch as judged by the user, against his/her goal with the product, the product properties and the context in which the product is used (Wever, Van Kuijk & Boks 2008) could result in what can be referred to as unwanted or anticipated side effects (Rooden and Kanis 2000).

To explore this mismatch in what was referred to as 'defining a good shower experience', performative definitions of so called *sustainability objects* (Covellec 2016) were utilised. Using the eco-showerhead as a case example, performative objects were defined according to design – colour, shape etc. and performance metrics e.g. flow rate, spray etc. of the product. Then a user study was conducted to determine the extent to which the delivered performance of the sustainable product, correlated with the desired performance of the user.

This study did confirm some degree of functionality mismatch even though the common denominator of the study was that all the products were sustainable by design. The functionality mismatch occurs primarily in the performance related metrics of the products i.e. number of functions, spray type and quality, number of sprouts and sprout layouts, as opposed to the more design oriented factors such as shape and colour. The findings therefore suggest that paying particular attention to the performative metrics of sustainability products during design, through labelling and marketing tools are therefore more likely to encourage the adoption of the product, as well as its effective and efficient use. The concluding premise of the work is therefore that water efficient (and more broadly, sustainability) products, needs to be designed with user performance definitions in mind. This in turn affects the extent to which the sustainable product is full accepted, adopted and sustainable-in-use.

The study is particularly significant because it goes beyond simply measuring sustainability product performance in terms of resource consumption values alone; and considers the role of design and performance features in improving user experience as well. Its output affirms both a physical and cognitive link between the design features and resulting perception of effectiveness of the product – showerheads in this instance. It was also found that there is scope for innate product features to be more obvious and intuitive. These considerations can contribute to future sustainability product design. The findings also highlight the influence of certain design features on how performance is perceived and experienced and although further study is required, also found that certain performance features can negate efficiency savings e.g. due to the need to shower longer to be effective in certain cleaning activities such as washing of hair. This study and its outputs are valuable in that they contribute real-world feedback based actual use and interaction with products by participants. This work is a compact trial study with scope for scaling up. It is also novel because it presents a different methodological approach for packaging and implementing user trials and studies which in turn promotes better participant engagement in research projects of this kind.

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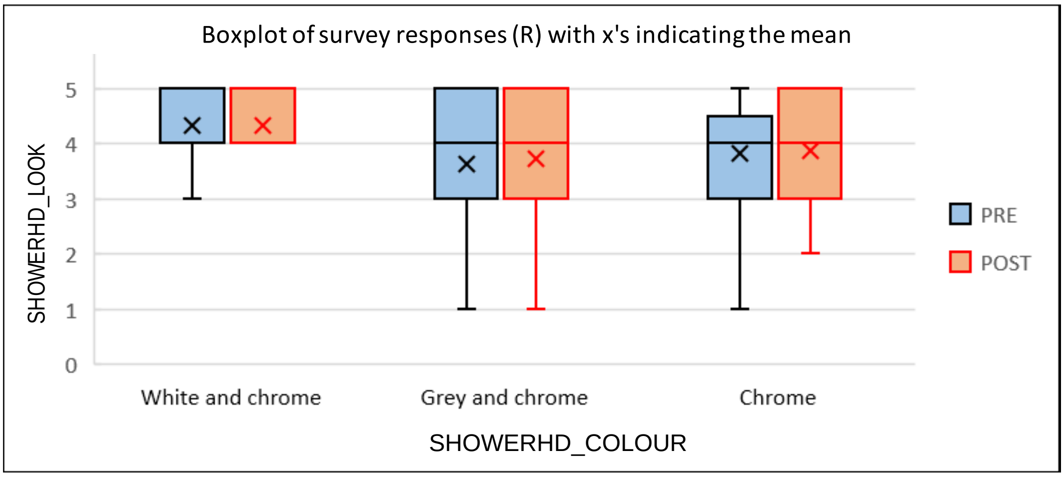


Figure 1: Showerhead appearance (colour) preference and both feedback stages during the trial week.

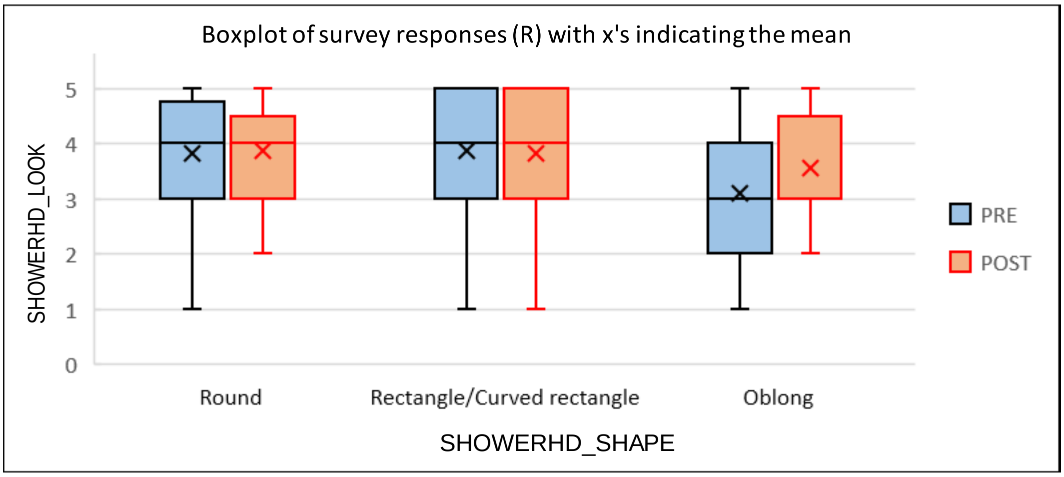


Figure 2: Showerhead appearance (shape) preference and both feedback stages during the trial week

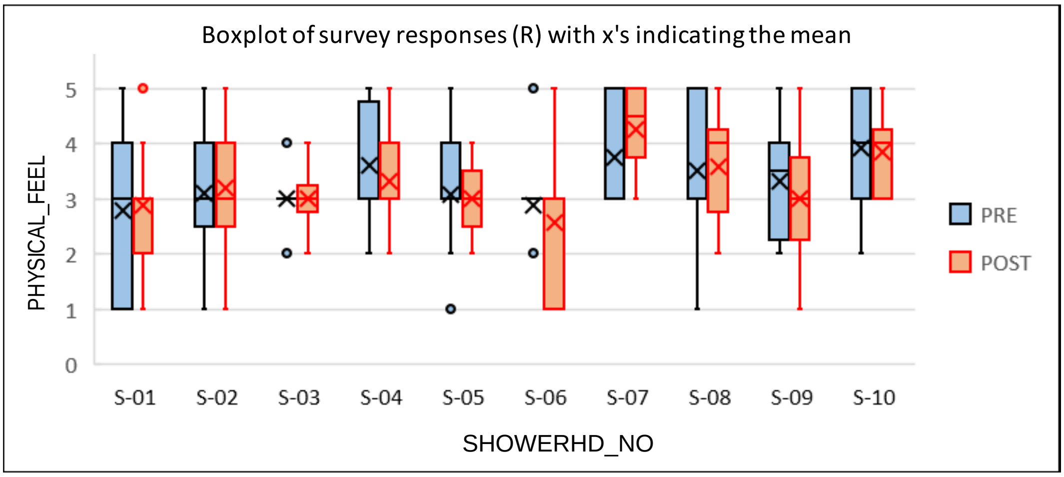


Figure 3: Comparative feedback on the physical feel of each showerhead

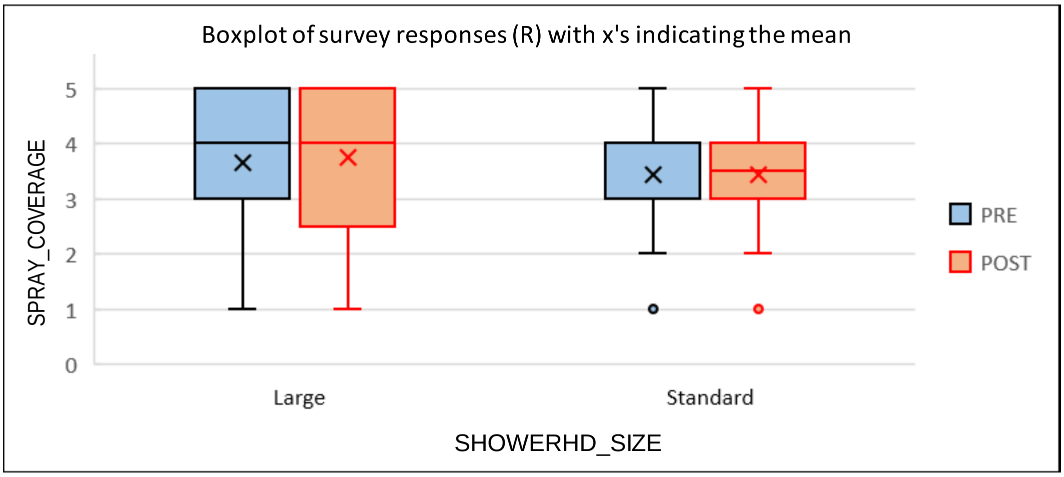


Figure 4: Comparative feedback on showerhead size relative to the spray coverage

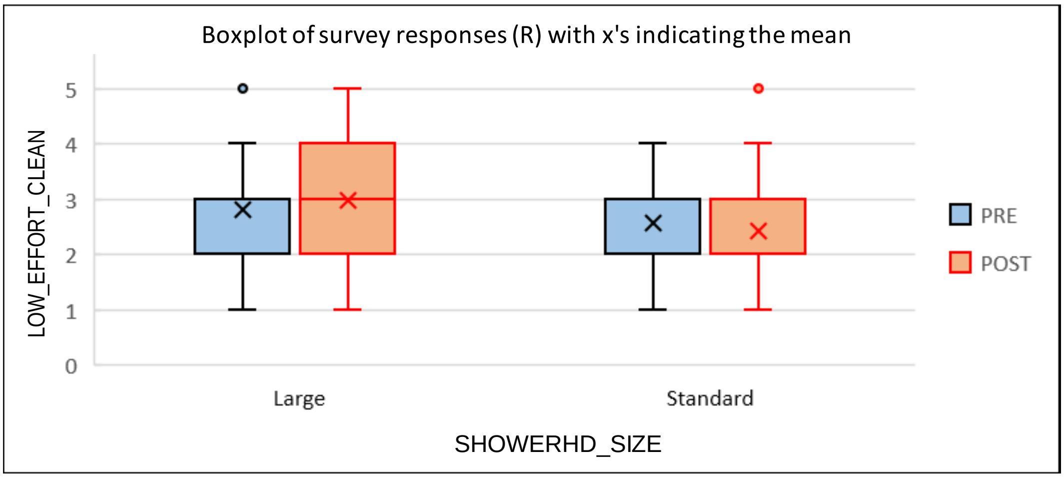
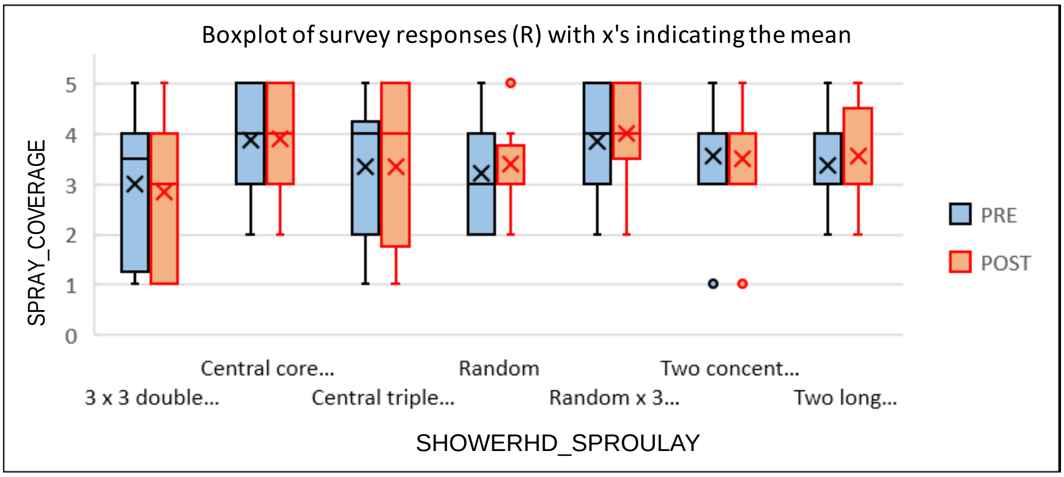


Figure 5: Influence of showerhead sized on perceived time it took to achieve an effective clean.



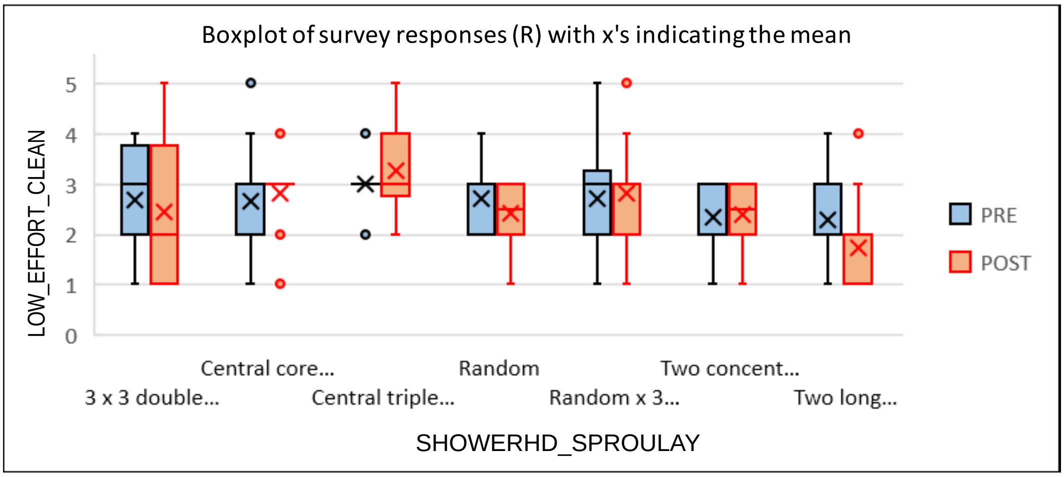


Figure 6a & b: Mean plot of influence of sprout layout on perceived time to clean and spray coverage

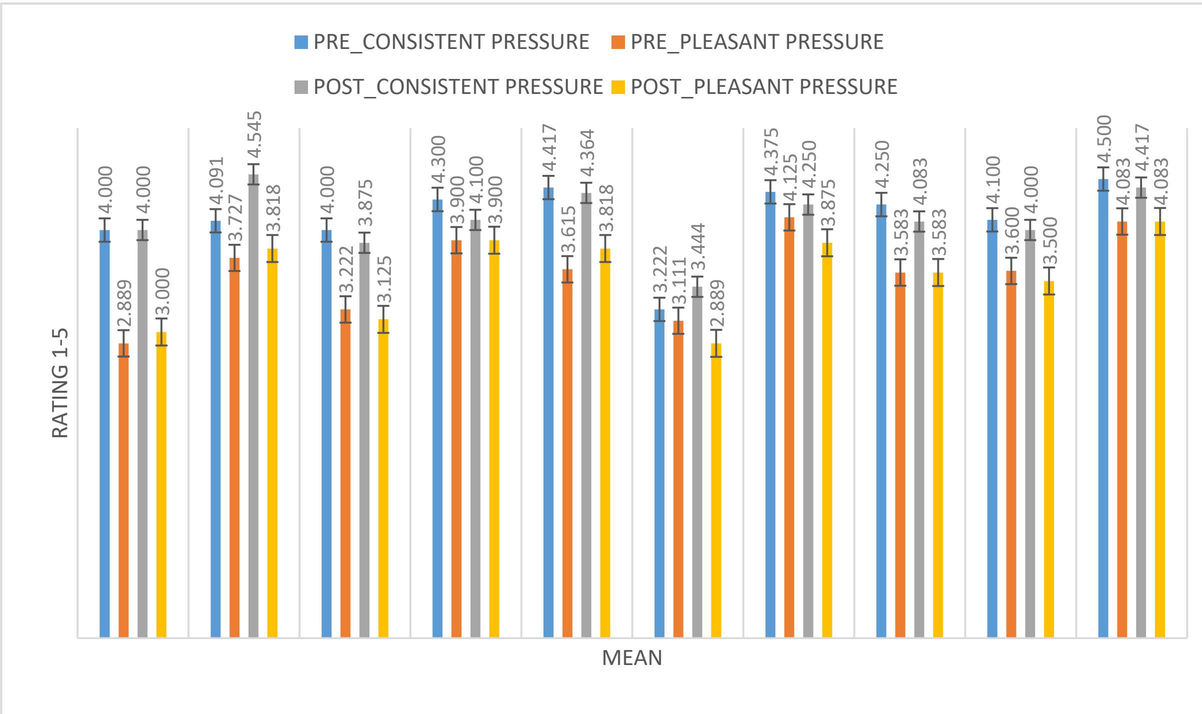


Figure 7: Mean plot of perceived consistency and pleasant feel of pressure at the beginning and end of the trial week per showerhead

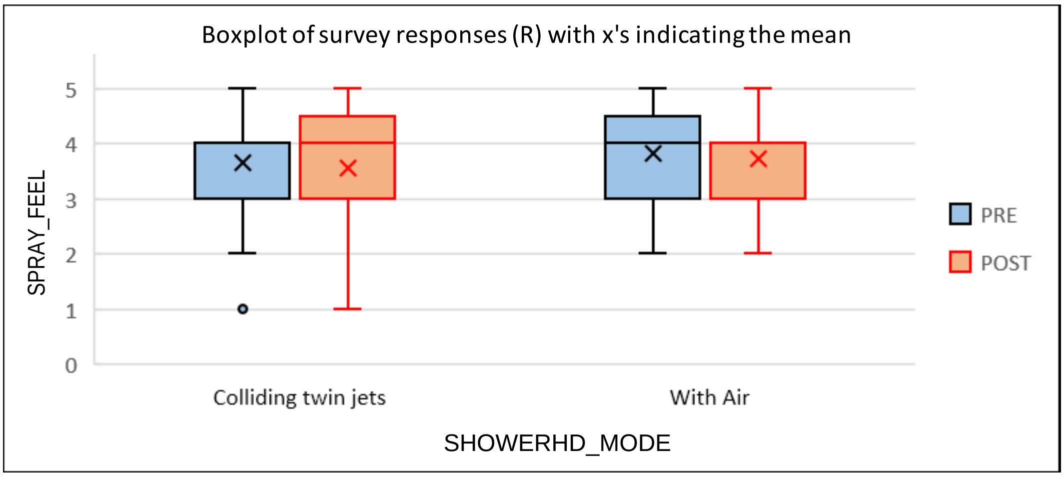


Figure 8: Shower mode versus perceived spray feel, as perceived at the beginning and end of the shower trial week.

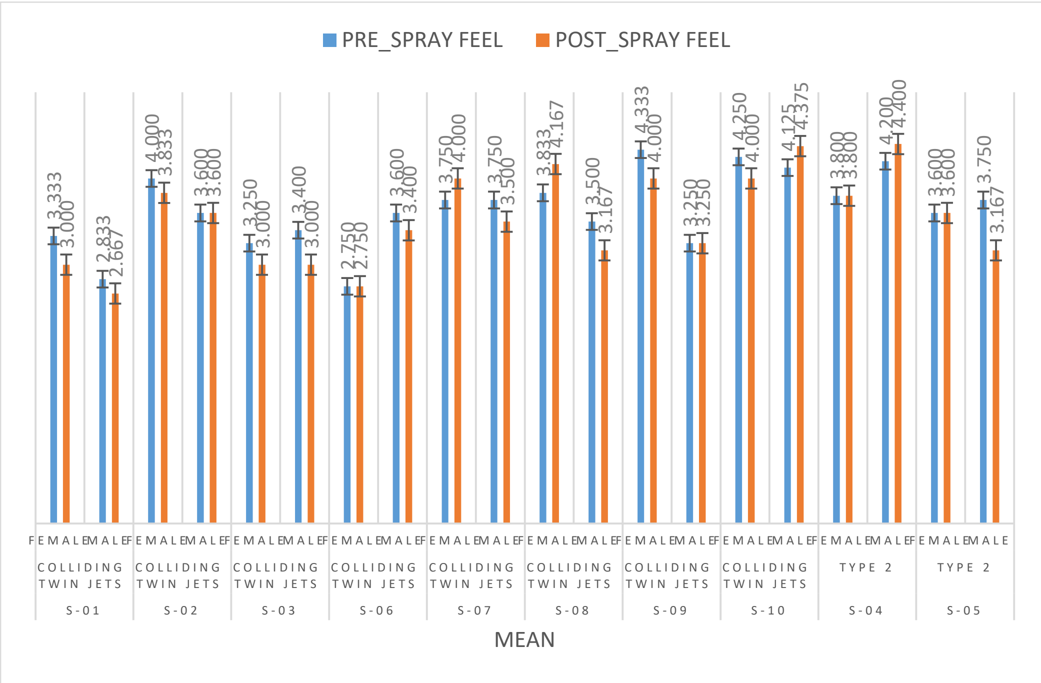


Figure 9: Shower mode versus perceived spray feel, as perceived at the beginning and end of the shower trial week.

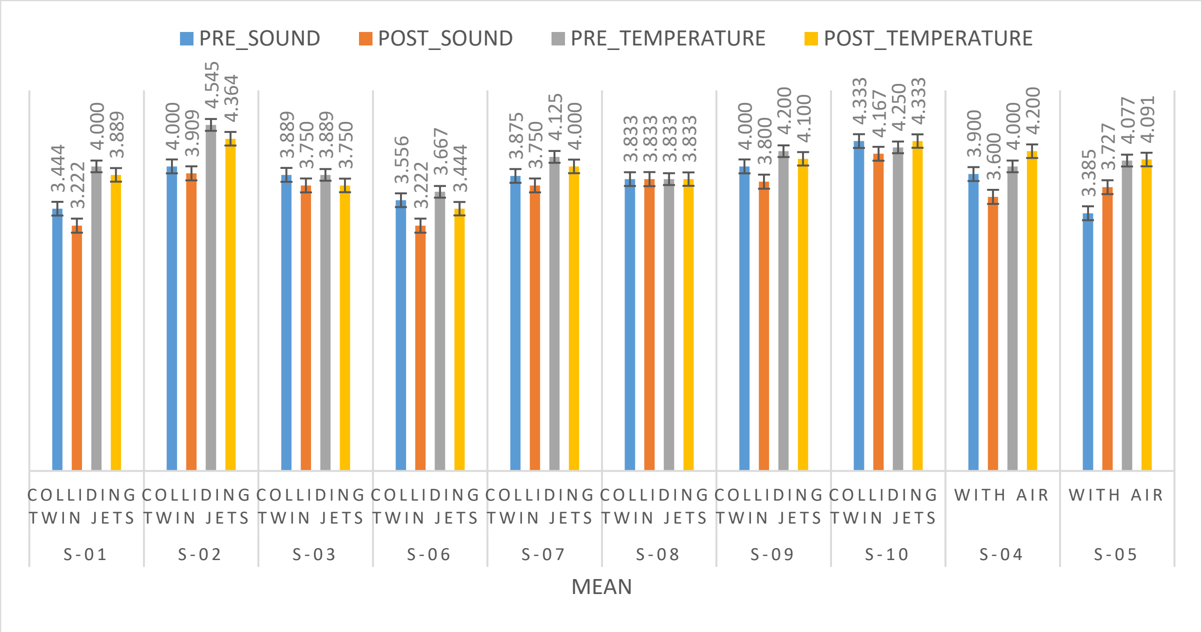


Figure 10: Shower mode and perceived temperature and acoustics characteristics.

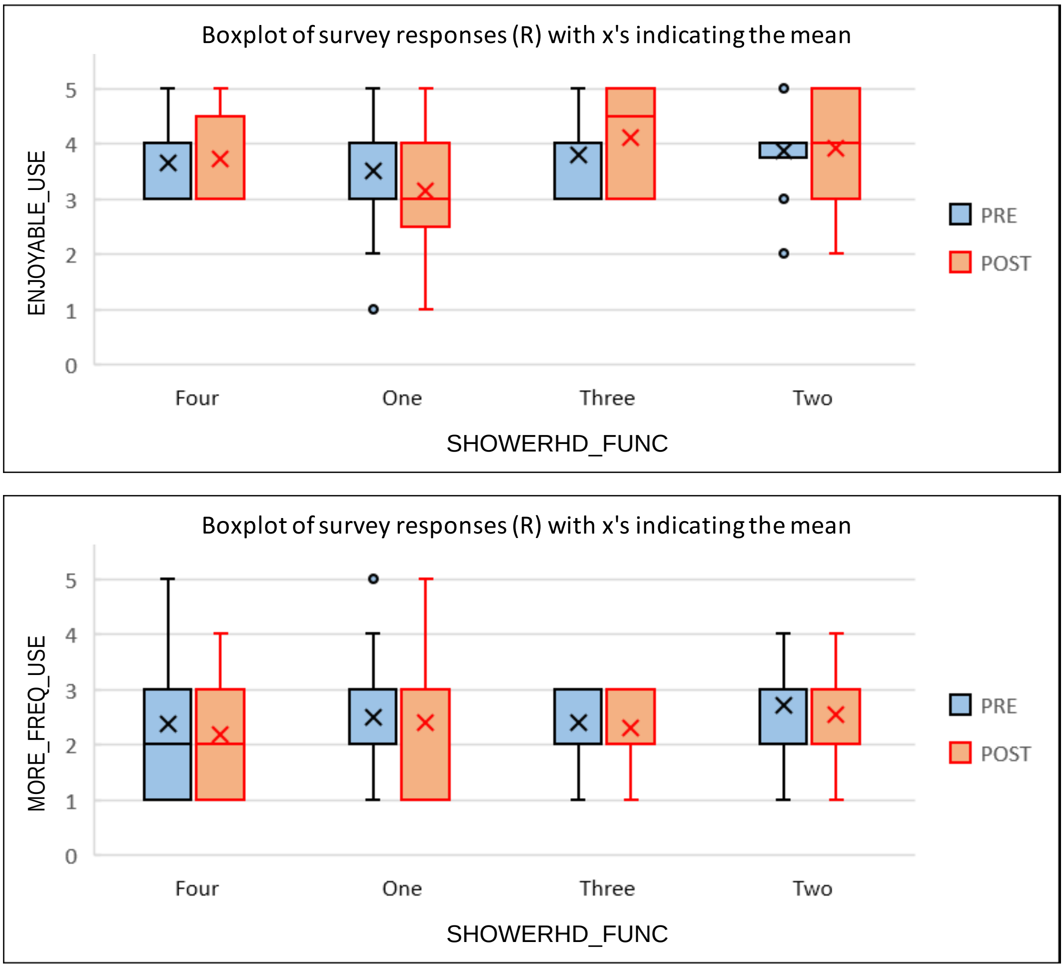


Figure 11a&b: Shower function and influence on enjoyability and frequency of use

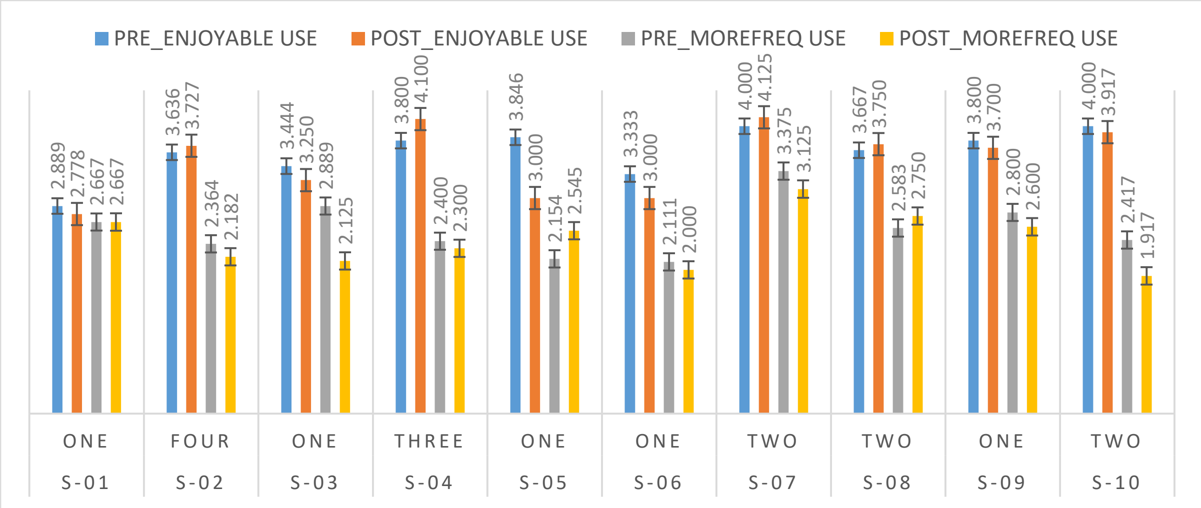


Figure 12: Shower mode and perceived temperature and acoustics characteristics.