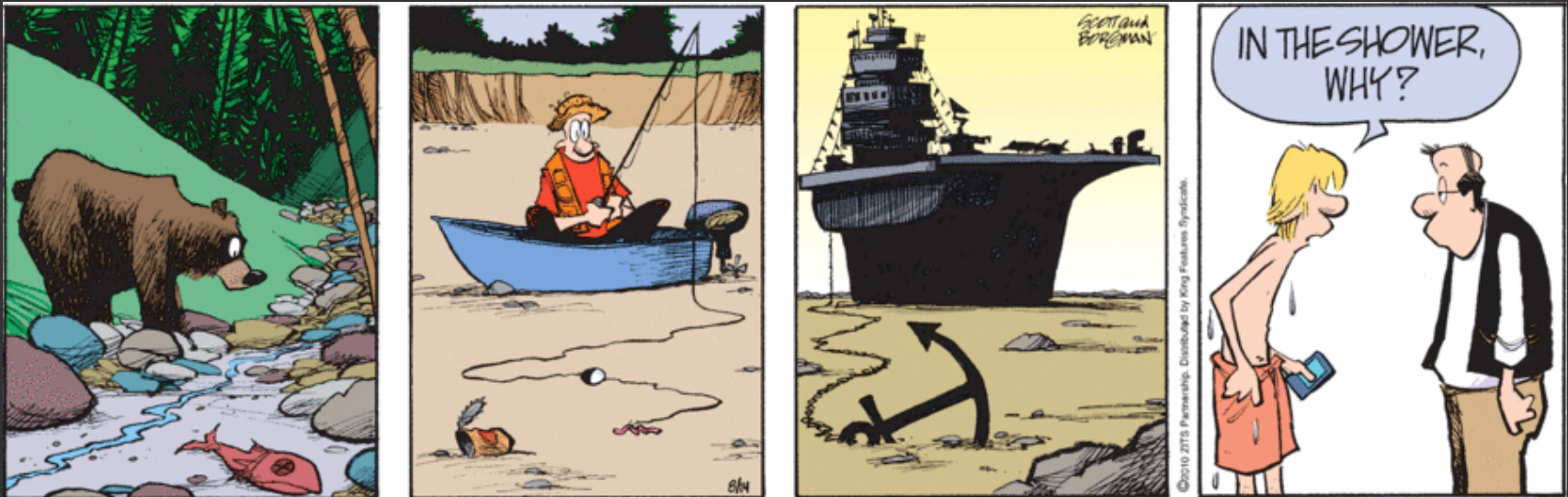# Showerheads experience: statistical analysis of the individual behaviour of the users

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According to several studies, user's decisions, behaviours and habits have a major effect on resource use be it energy or water.

Beal et al. (2011) found that shower use contributes an average of around 30% of the total household consumption in Australia and the UK.
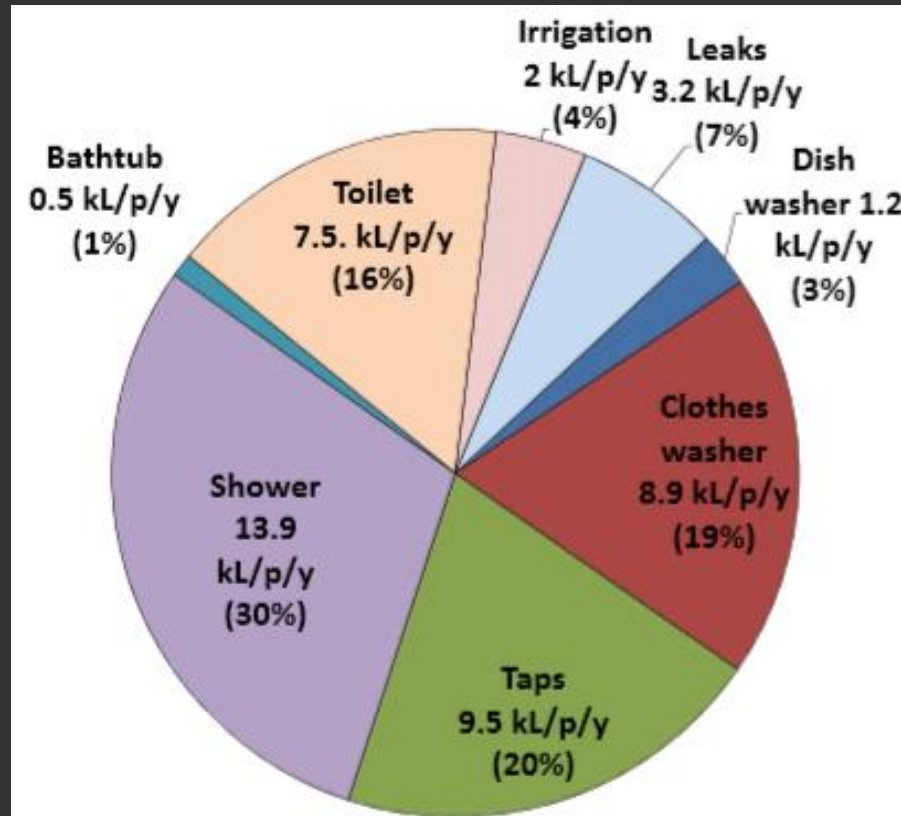
This makes engineered / higher efficiency water using devices such as water efficient showerheads an important strategy for delivering effective reductions in water consumption.

INSTALL
A WATER-EFFICIENT
SHOWERHEAD

This paper sits within a wider body of work which aims to understand the technical efficiency of showerheads as well as the extent to which it is efficient-in-use based on other qualitative metrics such as the user, perceptual and experiential factors.

Aim of the study

Statistical study to investigate the correlations and differences between water use factors such as duration and volume (discharge), against user and water efficient showerhead types.

This paper also provides insights into how quantitative methods and analysis can be beneficial for understanding the qualitative implications of water efficiency interventions; such as the tendency for users to make behavioural adjustments according to the perceived performance of water efficient products.

Methodology

Analysis of data from 12 users, in 10 showerheads, for 10 weeks. Further details found in Adeyeye et al (2017).

Statistical tests were applied to evaluate:

i)   If there are differences in the shower event durations and amounts of water used as a result of using the different showerheads.

ii)   The possible explanations underlying the distinct behaviours from the various users when using the same showerhead.

The methodology comprises the following steps:

i)   Data preparation, including the codification of the non-numerical information in the dataset.

ii)   Preliminary data analysis and assumption checking.

iii)   Testing the difference between the shower events durations and volumes changes.

Results

Parametric or non-parametric tests can be carried out in order to compare if the mean values between two distributions are statistically distinct.

Parametric tests are considered more powerful than non-parametric, but require the data to be normally distributed across each group and to be without outliers.

Results

The Shapiro-Wilk and Kolmogorov-Smirnov tests reveal that the duration and the water consumption of the shower event are not normally distributed for several users.

Example of user 1:

Variable	Showerhead	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Duration (min)	2	0.360	7	0.007	0.664	7	0.001
	3	0.484	12	0.000	0.465	12	0.000
	4	*0.293*	*6*	*0.117*	*0.915*	*6*	*0.473*
	5	0.421	7	0.000	0.646	7	0.001
	7	0.414	7	0.001	0.630	7	0.001
	8	*0.285*	*6*	*0.140*	0.711	6	0.008
	9	0.504	7	0.000	0.453	7	0.000
	10	0.367	5	0.026	0.684	5	0.006
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a. Lilliefors Significance Correction

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Duration (min)	2	0.367	5	0.026	0.684	5	0.006
	4	0.268	6	,200[*]	0.862	6	0.197
	5	0.322	8	0.014	0.753	8	0.009
	6	0.251	8	0.148	0.924	8	0.459
	8	0.492	6	0.000	0.496	6	0.000
	9	0.228	7	,200[*]	0.934	7	0.582
	10	0.192	8	,200[*]	0.926	8	0.477
	11	0.175	3		1.000	3	1.000
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As such, only non-parametric tests were used in the analysis:

- the Mann-Whitney U test, for comparing two groups;

- the Kruskal-Wallis test, for comparing three or more groups.

I - Analysis of each user separately

User profiles:

Users	Gender	Age	Highest qualification	Height	Weight	Income	Ethnicity	Relationship	Religious beliefs	Employment
1	Female	35 - 44	PG degree, Doctorate	156-160cm (to 5ft 3inches)	51-55kg	£40,000 - £49,1003	Polish Catholic & Jewish	Married or domestic partnership	All	Employed (full-time)
2	Female	25 - 34	Bachelor Degree	151-155cm (to 5ft 1inches)	51-55kg	£20,000 - £29,1004	White	Married or domestic partnership	No religion	Employed (full-time)
3	Female	35 - 44	PG degree, Doctorate	171-175cm (to 5ft 9 inches)	71-75kg	£60,000 or more	White	Married or domestic partnership	No religion	Employed (full-time)
4	Female	35 - 44	PG degree, Doctorate	151-155cm (to 5ft 1inches)	56-60kg	£20,000 - £29,1003	White	Single, never married	No religion	Employed (full-time)
5	Female	45 - 54	PG degree, Doctorate	156-160cm (to 5ft 3inches)	56-60kg	£20,000 - £29,1000	White	Divorced	No religion	Employed (part-time)
6	Female	25 - 34	PG degree, Doctorate	151-155cm (to 5ft 1inches)	90Kg +	£30,000 - £39,999	White	Married or domestic partnership	No religion	Employed and studying (part-time)
7	Male	35 - 44	PG degree, Doctorate	171-175cm (to 5ft 9 inches)	76-80kg	£60,000 or more	Mixed/Multiple ethnic groups	Married or domestic partnership	Christian	Employed (full-time)
8	Male	25 - 34	PG degree, Doctorate	180cm and more (6ft +)	76-80kg	£20,000 - £29,999	White	Single, never married	Christian	Employed (full-time)
9	Male	25 - 34	Currently studying	166-170cm (to 5ft7inches)	76-80kg	£20,000 - £29,1001	White	Married or domestic partnership	No religion	Student
10	Male	45 - 54	Professional qualification	166-170cm (to 5ft7inches)	71-75kg	£60,000 or more	White	Married or domestic partnership	No religion	Employed (full-time)
11	Male	35 - 44	Professional qualification	171-175cm (to 5ft 9 inches)	66-70kg	£60,000 or more	Asian/Asian British	Married or domestic partnership	No religion	Employed (full-time)
12	Male	35 - 44	Further Education/ College	176-180cm (to 5ft 11inches)	66-70kg	£50,000 - £59,999	White	Married or domestic partnership	No religion	Employed (full-time)

Results

Kruskal-Wallis test reveals that for the different showerheads:

-the duration and water consumption are statistically distinct for users 1, 2, 5, 8 and 10;

- for users 4, 6, 7, 9 and 12 the duration is not statistically distinct but the water consumption is;

- no statistically significant difference was found either for duration or water consumption for users 3 and 11.

Results

User	Variable	Duration (min)	Water consumption (l)
1	Total N	57	57
	Test Statistic	25,342[a]	33,561[a]
	Degree Of Freedom	7	7
	Asymptotic Sig.(2-sided test)	0.001	0.000
2	Total N	47	47
	Test Statistic	19,303[a]	43,429[a]
	Degree Of Freedom	7	7
	Asymptotic Sig.(2-sided test)	0.007	0.000
3	Total N	12	12
	Test Statistic	4,780[a,b]	5,313[a,b]
	Degree Of Freedom	2	2
	Asymptotic Sig.(2-sided test)	0.092	0.070
4	Total N	39	39
	Test Statistic	11,354[a,b]	25,457[a]
	Degree Of Freedom	6	6
	Asymptotic Sig.(2-sided test)	0.078	0.000
5	Total N	61	61
	Test Statistic	29,373[a]	42,383[a]
	Degree Of Freedom	8	8
	Asymptotic Sig.(2-sided test)	0.000	0.000
6	Total N	67	67
	Test Statistic	6,190[a,b]	23,105[a]
	Degree Of Freedom	8	8
	Asymptotic Sig.(2-sided test)	0.626	0.003
7	Total N	47	47
	Test Statistic	5,865[a,b]	20,133[a]
	Degree Of Freedom	5	5
	Asymptotic Sig.(2-sided test)	0.320	0.001
8	Total N	77	77
	Test Statistic	25,939[a]	43,775[a]
	Degree Of Freedom	8	8
	Asymptotic Sig.(2-sided test)	0.001	0.000
9	Total N	66	66
	Test Statistic	8,460[a,b]	24,729[a]
	Degree Of Freedom	9	9
	Asymptotic Sig.(2-sided test)	0.489	0.003
10	Total N	67	67
	Test Statistic	15,754[a]	34,394[a]
	Degree Of Freedom	7	7
	Asymptotic Sig.(2-sided test)	0.027	0.000
11	Total N	36	36
	Test Statistic	12,177[a,b]	13,817[a,b]
	Degree Of Freedom	7	7
	Asymptotic Sig.(2-sided test)	0.095	0.055
12	Total N	45	45
	Test Statistic	11,416[a,b]	26,542[a]
	Degree Of Freedom	8	8
	Asymptotic Sig.(2-sided test)	0.179	0.001

a. The test statistic is adjusted for ties.
b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Discussion:

Duration

- the majority of the users do not change their showering pattern, enabling the lower discharge showerheads to produce a statistically significant reduction in water consumption;

- these results are indications that these water efficient devices provide most users an equivalent level of comfort so that they do not change their showering habits.

Water consumption

- even if some users change their showering pattern, a statistically significant reduction in water consumption is still observed but for 2 users;

- these results are indications that even if these water efficient devices force the users to change their showering habits, the discharge reduction still compensates this change in behaviour, contributing to save water.

II - Analysis of each showerhead separately

showerhead characteristics:

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 (mm)	90	157	106	100	100	106	135	67	65	135
Width (mm)	90	82	106	100	100	106	135	182	120	135
Height incl. handle (mm)	215	270	239	230	230	239	246	227	219	246
Regulated flow rate @ 2 bar pressure (L/m)	8.7	8.7	7.9	13.2	12.9	5.1	7.6	7.4	8.3	7.6
Number of functions	1	4	1	3	1	1	2	2	1	2
Image										

Results

Mann-Whitney U test reveals that:

- the duration and water consumption for males and females are statistically distinct for showerheads 1, 4, 6, 9 and 10.

- no statistically distinct water consumption was found for showerheads 2, 3, 5, 7 and 8.

Results

Showerhead	Variable	Duration (min)	Water consumption (l)
1	Total N	56	56
	Mann-Whitney U	142.000	142.000
	Test Statistic	142.000	142.000
	Standard Error	56.811	56.811
	Standardized Test Statistic	-3.520	-3.520
	Asymptotic Sig.(2-sided test)	0.000	0.000
2	Total N	78	78
	Mann-Whitney U	792.500	792.500
	Test Statistic	792.500	792.500
	Standard Error	99.576	99.576
	Standardized Test Statistic	0.326	0.326
	Asymptotic Sig.(2-sided test)	0.744	0.744
3	Total N	55	55
	Mann-Whitney U	297.000	297.000
	Test Statistic	297.000	297.000
	Standard Error	58.693	58.693
	Standardized Test Statistic	-1.363	-1.363
	Asymptotic Sig.(2-sided test)	0.173	0.173
4	Total N	63	63
	Mann-Whitney U	207.000	207.000
	Test Statistic	207.000	207.000
	Standard Error	72.226	72.226
	Standardized Test Statistic	-3.987	-3.987
	Asymptotic Sig.(2-sided test)	0.000	0.000
5	Total N	71	71
	Mann-Whitney U	476.000	476.000
	Test Statistic	476.000	476.000
	Standard Error	83.846	83.846
	Standardized Test Statistic	-1.407	-1.407
	Asymptotic Sig.(2-sided test)	0.159	0.159

Results

Showerhead	Variable	Duration (min)	Water consumption (l)
6	Total N	49	49
	Mann-Whitney U	143.500	143.500
	Wilcoxon W	468.500	468.500
	Test Statistic	143.500	143.500
	Standard Error	49.488	49.488
	Standardized Test Statistic	-3.162	-3.162
	Asymptotic Sig.(2-sided test)	0.002	0.002
7	*Total N*	*48*	*48*
	Mann-Whitney U	*223.500*	*217.500*
	Test Statistic	*223.500*	*217.500*
	Standard Error	*47.919*	*48.101*
	Standardized Test Statistic	*-1.304*	*-1.424*
	Asymptotic Sig.(2-sided test)	*0.192*	*0.154*
8	Total N	72	72
	Mann-Whitney U	577.500	577.500
	Test Statistic	577.500	577.500
	Standard Error	88.102	88.102
	Standardized Test Statistic	-0.778	-0.778
	Asymptotic Sig.(2-sided test)	0.437	0.437
9	Total N	57	57
	Mann-Whitney U	52.500	52.500
	Test Statistic	52.500	52.500
	Standard Error	60.777	60.777
	Standardized Test Statistic	-5.570	-5.570
	Asymptotic Sig.(2-sided test)	0.000	0.000
10	Total N	72	72
	Mann-Whitney U	379.000	379.000
	Test Statistic	379.000	379.000
	Standard Error	83.128	83.128
	Standardized Test Statistic	-2.370	-2.370
	Asymptotic Sig.(2-sided test)	0.018	0.018

Discussion:

Duration & Water consumption

- the difference found between water consumption for males and females in some showerheads might indicate that these water efficient devices do not provide to female users an equivalent level of comfort as to male users, probably causing a change on their showering habits.

Conclusion

This paper uses statistical methods to investigate the individual behaviour of the users when using different showerheads.

Water savings are possible using water efficient showerheads for the large majority of users, since the eventual duration adjustment from behavioural change may affect but do not hinder the potential savings completely.

There seems to be distinct behaviour from males and females to the different showerheads, particularly when the discharge is high or low.