New directions in understanding household water demand: a practices perspective

Martin Pullinger, Ben Anderson, Alison Leigh Browne and Will Medd

ABSTRACT

Understanding the nature of current household water use is important for forecasting future demand and for designing effective water efficiency interventions. This paper argues that to develop this understanding further it is necessary to shift away from the current focus on sociodemographic characteristics as predictors of litres used towards the everyday practices of household members through which water is consumed, i.e. routine and often habitual activities such as watering the garden, showering and clothes washing. It presents selected results from a survey of water using practices undertaken in southern England in 2011, focusing on garden watering as an example which demonstrates some of the added understanding that such a 'practices approach' brings to how water is being used. These serve to illustrate that how individuals water the garden varies, often with little relationship to their sociodemographic characteristics. Further results demonstrate too that how individuals perform different practices varies with little relationship between the practices, so that even a set of households with similar levels of daily per capita water use can be using it in widely different ways. We end with some examples of how this understanding could help in demand forecasting and in designing more effective approaches to interventions.

Key words | everyday practice, household water use, practice theory, water demand forecasting, water demand interventions

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INTRODUCTION

Water demand management is increasingly seen as an important way to maintain balance in the water supply and demand system (DEFRA 2008; Environment Agency 2009a, b), and is seen as a 'low regret' form of intervention (Gleick 2002; United Nations 2006), i.e. even with uncertainty over the exact outcomes, the overall costs versus benefits are unlikely to be high. However, current approaches to forecasting future demand are based on behavioural models of household water use which capture little of the observed variance between households, whilst the effectiveness of interventions, such as information campaigns to raise awareness of water use among household consumers, is often less than expected (Browne *et al.* 2013).

In this paper we take up this issue and argue that current ways of understanding and approaching water demand forecasting and interventions would benefit from supplementary methods to improve their effectiveness. We review the current dominant approaches to forecasting demand and designing interventions, which draw on behavioural economics and psychology, and discuss how incorporating a 'practices perspective' can increase our understanding of how water use in the home is constituted. Such a perspective draws on sociological research that is often termed 'practice theory', which focuses on everyday routines and habits ('social practices') such as watering the garden, showering and clothes washing, how they are performed by individuals, and the personal and contextual factors which shape those individuals' actions. In doing so we show why sociodemographic characteristics and values are generally poor predictors of final water use. Firstly, this is because how and why particular practices such as gardening are performed in certain ways may be influenced by individual

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characteristics, but they are also mediated by complex distributed influences from cultural norms and meanings, systems of provision and technologies. Secondly, how these practices are performed in turn do not necessarily allow for direct estimation of the water use involved, again because of the diversity of mediating factors.

In addition, the practices approach allows us to move beyond the 'average consumer' (average in terms of their daily consumption of water, in litres) to look at this diversity in the population in the everyday practices which shape water use.

To do this, we have applied a practices approach in a mixed methods (integrated quantitative and qualitative) empirical study for, to our knowledge, the first time in water research to investigate the diversity in the ways in which individual water using practices vary in the population, and to search for common variants and the influence of individual and household factors upon which variant a person will 'host' (Shove 2012). The research forms part of the ARCC-Water and SPRG Patterns of Water projects (see 'Acknowledgements').

The approach used in this research has led to a new and detailed description of the common everyday practices which use water. Whilst the research covered all aspects of domestic water use, from personal care and clothes washing to gardening and kitchen practices, this paper concentrates primarily on garden watering, both as an example of the kind of additional understanding of how water is used in the home that the approach can provide, and because it is the only water 'practice' over which there is direct external control (through hosepipe bans) and consequentially political contention. In the results section of this paper, we present the common variants of gardening practices found in the population, and illustrate the weak power of sociodemographic characteristics and environmental behaviours in predicting which variant people perform. We also present evidence that the ways in which people perform the different water using practices also vary largely independently of one another, so that we find huge diversity in the variants of practices performed by any given set of seemingly 'average water users', implying they are likely to be amenable to influence by differing interventions, and could follow substantially different future trajectories in water use.

Reflecting on the results in the discussion, we argue that drawing more on sociological research into everyday practices would be valuable for water demand managers and those involved in forecasting future water demand. The approach of focusing on practices provides a valuable additional avenue through which to understand how individuals are using water and to explore the diverse factors which influence this beyond the individual's characteristics and values. We reflect on the potential of practices research to support water demand management in the water industry by contributing new knowledge to help the development of more diverse and effective demand management interventions. We also discuss how the approach can be used, to complement existing demand forecasting techniques with sociologically richer descriptions of possible scenarios of future water demand.

LITERATURE REVIEW

Current dominant approaches to forecasting and influencing water demand draw on psychology and behavioural economics. A household's overall per capita consumption (pcc) of water is predicted based on socioeconomic characteristics and, increasingly, their environmental values as revealed in surveys (Arbués *et al.* 2003, 2010; Memon & Butler 2006; McDonald *et al.* 2011). These relationships can then be used to predict water use in a given area based on socioeconomic data on the households within it (drawn from census surveys), and forecast based on predicted future population and demographic changes, incorporating different scenarios of change in environmental attitudes (e.g. Environment Agency 2009b, Appendix 2). A key problem is that this approach fails to account for a large percentage of the observed variance in household water usage. A further approach takes this further to look at how technology change, environmental (weather) changes and other group level variables might affect water use. This focuses on analysis of micro-component usage, drawing on data from households which have had meters installed to record water usage at different sites within the home (e.g. showers, toilets, kitchen sinks, outdoor taps, etc.). This 'OVF' approach looks at how ownership of technologies (O), volume used per usage (V) and frequency of usage (F) vary with sociodemographics and with changes in these weather and other group level variables (Herrington 1996, 1998;

Downing et al. 2003), which can then be used to estimate change in the future. These data have been useful in demonstrating how even households with similar pcc vary substantially in terms of how that total is arrived at, in terms of the different sites in the home where the water is used, which gives an insight into why so much variance is unaccounted for by sociodemographic predictor variables (Medd & Shove 2006).

Interventions meanwhile increasingly focus on placing responsibility for reducing water use onto the household or individual (Scerri 2011). Approaches taken include delivering more water efficient technologies to households and the provision of information to highlight either the individual financial benefit involved in changing certain routine behaviours (at least, for the 40% or so of UK households who currently have a water meter), or the environmental benefit, appealing to environmental values (McKenzie-Mohr 2000). These assume a rational actor model, where consumers will seek to maximise the efficiency with which they meet their preferences for watering the garden (for example) given the right technology and information. However, the effectiveness of such approaches can be limited: there is a well-observed 'value action gap' (Gregory & di Leo 2003) in people's behaviour – a disjoint between reported attitudes towards the environment and actual actions to reduce water use (see, for example, Russell & Fielding (2010) for a review of studies), whilst household water use is typically quite inelastic to price (Arbués et al. 2003, 2010; Schleich & Hillenbrand 2009). Such approaches also target relatively minor changes in individual actions, reducing the associated water use in each performance of a practice (increasing its 'efficiency') rather than attempting to alter the underlying, systemic structures which encourage and lock in particular ways of meeting preferences, or indeed which shape individuals' preferences for particular practices (Watzlawick et al. 1974; Sofoulis 2011).

There is therefore a need to move beyond predicting average water demand towards understanding the varied way in which that average is constituted, to give a more nuanced insight into how water use might vary in future, and how water use might be influenced. To do this we turn to the sociological conception of 'social practices' (e.g. Shove 2004; Warde & Southerton 2012) which has been shown to be an effective way to move the unit of analysis away from focusing on the consumer, or indeed on the water used, to the everyday habits and routines in which people engage. It is an approach that is increasingly being used within the literature on water (and energy) use and demand management, and other areas of household sustainability, and has a particularly strong history of use within the UK, Australia and Europe (e.g. Shove 2004; Hand et al. 2005; Allon & Sofoulis 2006; Gram-Hanssen 2008; Kuijer & de Jong 2009; Halkier et al. 2011; Horne et al. 2011; Strengers 2011; Taylor & Trentmann 2011; Pink 2012; Strengers & Maller 2012).

By focusing first and foremost on what people do, how and why they do it, and what they use when doing it, the approach reveals the often inconspicuous and habituated enactments of everyday practice, the links between these enactments and available technologies and infrastructures (i.e. the material 'stuff' of consumption), and aspects such as cleanliness, comfort, ideas of the 'good life', and other cultural and social images and conventions shaping practice in homes and gardens (Shove 2004). These approaches connect the everyday to the more historical approaches that explore the development of systems of provisions (e.g. the development of water infrastructures), broader cultural and medical agendas (e.g. emerging agendas around consumer rights, health and hygiene), and other elements of consumption (Strang 2004; Sofoulis 2005; Allon & Sofoulis 2006; Taylor & Trentmann 2011; Warde & Southerton 2012). It therefore draws attention to the way that individual performances of these everyday practices is shaped not just (or even mostly) by their values and attitudes towards water and the environment and by economic imperatives to initiate change, but also by diverse systemic, technological and social factors. This practice-based approach therefore has the potential to shed new light on how and why water is used and the distributed factors which shape and influence individual and overall water demand. This can be of value to those involved in forecasting future water demand and in designing interventions to influence demand.

METHOD

To date the majority of research using a practices perspective has been qualitative, small-scale studies, which whilst extremely valuable for increasing understanding of how specific practices have emerged, are sustained and/or fade, have had limited impact on water demand management techniques which require quantitative results. In contrast, this paper makes use of a large-scale, quantitative 'water practices' survey matched with subsequent qualitative in-sample interviews, intended to produce a grounded but quantitative picture of the diversity of water using practices. The survey recruited a total of 1802 households from the south east of England in the summer of 2011, comprising a representative sample of the population of that region. 997 households were selected randomly from the Government Office Regions of the South, East and South East of England and a further 805 households were selected randomly from within specific case study areas of those Government Office Regions where our collaborating water companies were able to provide area-based metering penetration and water consumption data through their own network of monitoring systems. Data were collected by interviewers using computer assisted personal interviewing, with particularly sensitive questions such as those relating to personal hygiene being self-administered by the participants using the fieldwork tablet (CASI – computer assisted self-interviewing).

Data were collected on the participants' habits and practices relating to personal hygiene and care, clothes laundering, gardening, vehicle washing, cooking, cleaning and washing up. Further data were collected on the water using equipment in the home, general sociodemographic characteristics, the presence of water meters, estimates of their most recent bill if metered, and a range of 'environmental' habits, such as turning off lights in rooms not in use, wearing more clothes rather than turning up the heating when cold, and using public transport over private car travel. Finally, permission was requested to link their survey responses to their daily water use data based on their water bills, including daily expenditure, as well as litres of water used where the households were metered, obtained from the participants' respective water companies. Unfortunately, various difficulties with linking these data, including a low level of granted permissions to do so by participants, means that for only 73 of the 1802 cases do we have water usage meter data linked to the survey responses.

Initial analysis (presented below) produced descriptions of the diversity of water-using practices found among the participants. In a second analytic step (also presented below) cluster analysis was then used to attempt to identify common variants of the main water-using practices in the population across the main water-using activities of gardening, bathing, laundry and cooking. The intended end result was an exploration of the value of classifying the population's practices into a range of variants (or clusters) of each practice. Cluster analysis is a method to aid identification of groups of cases such that cases within each group are more similar to each other than they are to those in other groups, defined in terms of their values along different 'dimensions'. The choice of variables to use for these dimensions is led both by underlying theory and by the intended research aims and applications, but there are elements of researcher choice in terms of which dimensions to include, how to operationalize variables which represent them, and the precise methods of cluster analysis used. The researcher, therefore, has a role in shaping the knowledge produced from the analysis so that it is of value to the aims of the research, which makes cluster analysis an approach that is consistent with other, qualitative, practices research in that it draws on a post-positivist rather than positivist paradigm which acknowledges the role of the researcher in shaping scientific knowledge and the assumptions embedded within it (Sharp *et al.* 2011).

For garden watering, we selected four dimensions to identify common variants, as presented below in Table 1. These represent certain constituent 'elements' of the practice (Shove *et al.* 2012), notably ones related to how and when it is physically performed, which in many cases might also be expected to have implications for final water use. Other elements, notably the reasons and meanings for performing the practice, and the systems of provision, are omitted from the cluster analysis because of the difficulty in operationalizing them into a linear scale as is required by the method, and instead are treated separately as factors which can influence how and why a person performs the practice as they do. Each participant is given a rating from 0 to 1 on each of the dimensions based on their survey responses, so that each dimension has equal weighting in identifying clusters. A common two-stage clustering method was used: firstly, an initial hierarchical cluster analysis was performed to identify the optimum number of variants (clusters) of gardening into which to divide the sample, and to identify the approximate mean values on

Table 1 | Dimensions of gardening practice used to identify variants (clusters) of gardening

Dimension	Definition	Scale values
Frequency	Whether the respondent waters the garden plants, lawn, and fruit and vegetables.	0 indicates no; 1 indicates yes.
Diversity	Number of factors which influence the timing of watering.	0 indicates none; 1 indicates 3 or more.
Technology	A measure of the watering technology used, approximately rated based on its relative potential water flow rate (average rating of the technology used on the lawn, garden plants, and fruit and vegetables).	0 indicates jug or watering can, or from water butt or recycled water from house; 0.4 indicates hosepipe without trigger; 0.5 indicates hosepipe with trigger; 0.7 indicates sprinkler; 0.8 indicates seep hose; 1 indicates automatic irrigation.
Efficiency	Efficiency of home mains water use (average rating of the water source used on the lawn, garden plants, and fruit and vegetables).	0 indicates mains water use; 0.5 indicates mix of water butt/recycled and mains; 1 indicates water butt or recycled.

each of the dimensions for each of the variants; a subsequent k-means cluster analysis was then performed to more accurately identify both the mean values for each cluster and the clusters to which each case belongs. Full details of the method are presented in Pullinger *et al.* (2013).

Further analysis using ordinary least squares and multinomial regression was performed to analyse how sociodemographics and environmental values predict cluster membership in each practice, and how well practices in turn predict water use for the 73 households for whom we have linked (metered) water consumption data. The relationship between how different practices relate to one another was also investigated.

RESULTS

The cluster analysis of gardening practices produced six distinct variants of gardening, defined by differences in the participants' scores on the dimensions described in Table 1 above. These included whether they reported watering the garden, how many factors influenced the timing of watering, the technology used to water the garden, and the efficiency of mains water use (with gardening using only rain-harvested or recycled water given the highest efficiency score, and gardening using only mains water given the lowest).

In terms of implications for water use and outside water control, some of the results are striking. 91% of the population in our sample reported having some kind of outdoor space, 87% having a back garden and 77% a front garden. 30% have a patio or smaller yard, and 3% have a balcony and 6% decking. However, fully 38% of the sample reported having nothing to water, and this constituted the largest cluster, or variant, of garden watering. As 67% of this group reported that they have a back garden, 56% a front garden, and 75% have at least some kind of outdoor space, this means either there are no plants or lawn in it, or that they do not consider what is there as something that they would water. A further 18% followed what we termed 'hands off gardening', reporting that they did have plants or lawn that required water, but that they never water the garden, waiting instead for the rain. Fully 56% of respondents, therefore, reported that their gardening practice involved no watering, with clear water (non)use implications. The majority of the remainder use mains water, with 18% following 'casual gardening', using mains water but usually using only low technology, such as jugs or watering cans, to do the watering; whilst 16% performed 'high tech gardening', utilising mains water and higher levels of watering technology, usually hosepipes, but also sprinklers and automated irrigation systems. The latter could therefore represent high-impact gardening in terms of the mains water required, whilst those performing casual gardening probably will not be able or willing to carry many litres of water to the garden.

The remaining two variants of gardening are performed by relatively few people: 'amateur enthusiastic gardening' and 'green fingered gardening' are followed by 5 and 6% of the population, respectively. The main difference from the casual gardening group is on the efficiency scale – amateur enthusiastic gardening uses a mix of mains and water butt water, so is in the middle of the efficiency scale, while green fingered gardening uses only water from a water butt, so is at the top of the scale. Practitioners of both tend to water with watering cans and jugs, but both groups have a small proportion of people who use other technologies such as hosepipes and sprinklers. Followers of both of these variants, especially green fingered gardening, are more likely to see their outdoor space as a place to grow their own fruit and vegetables, and both groups are also the most likely to see their garden as a place for wildlife and birds, and to have garden ponds and water features, including for the birds and wild animals.

The different variants of garden watering above would be expected to result in substantially different relative levels of mains water use outside the house, with high tech gardening likely to use the most mains water, and hands off gardening and those with nothing to water using least (presumably none) for gardening. In principle green fingered gardening would also use no mains water, although in practice qualitative interviews with some of the respondents revealed that some of those who reported using only water butts for their water actually filled them from the mains at times! In practice, the difficulty of measuring sufficient heterogeneity of an individual's practices suggests predicting water use based on the small sample of linked metered households in this study would be difficult. Analysis of the relationship between variety of practices and overall household water use has been carried out, but the small sample size means that even the indicative results which suggest that practice clusters do offer some value in predicting water use are insufficiently robust to be confidently reported here. However, we return to the potential of practices to predict water use *in principle and with larger sample sizes* in the discussion section below.

Despite this difficulty, the results do demonstrate how information about practices reveal substantial further complexity and variation between households in their water use that is masked by averages and measures of overall, or even micro-component, meter readings. Two further factors suggest that this in turn will impact on the performance of methods to design and target interventions and to predict future water use that rely on household sociodemographic characteristics and/or customer segmentation based on environmental values. Firstly, such variables prove to be poor predictors of cluster membership and secondly, 'average' water consumption levels can be generated through a wide range of very different practices, as evidence below from analysis of the survey responses demonstrates.

In terms of cluster membership, even for gardening, where the strongest predictive power was found, only 15% of variance in cluster membership is predicted by sociodemographic variables and reported environmental actions (based on pseudo r squared for a multinomial logistic regression onto clusters). Results for the regressions are presented in Table 2. Environmental actions have some predictive power, with both amateur enthusiast gardening and green fingered gardening being associated with higher aggregate frequencies of environmental actions, and those with nothing to water with lower aggregate frequencies, compared to casual gardening. Amateur enthusiastic gardening is also more likely to be found among multiple car owners (an indicator of affluence) compared to casual gardening. Compared to casual gardening, having nothing to water is associated more with living in flats, renting, being under 65 years old, and being non-white, which could all be indicators of lower income and having a home that has little or no outdoor space.

Secondly, taking pcc as the starting point, the practices data reiterate the point made by Medd & Shove (2006) using micro-component data, that behind the 'average' consumer studied in linear models of water demand there is actually great variety in the practices which lead to that end level of overall water use. We repeat this analysis here using the current dataset, selecting, from the households for which we have data on their water usage based on their meter readings, five with close to current national average daily pcc of water, which is approximately 150 l per day (DEFRA 2008), and analysing variation in their practices, in terms of the clusters to which they belong.

To control for the potential effect of numbers of household members on pcc and respondent practices, only single occupancy households were selected. Their pcc ranges from 144 to 166 l per day. All the individuals had outdoor space with things requiring watering, all report having front and back gardens and patios, but no balconies or decking. Table 3 shows the differences in cluster membership of the five respondents for the practices for which we found clusters: gardening, washing, and laundry. Full descriptions of the different variants of washing and laundry can be found

Table 2 | Multinomial logit results of predictors of gardening cluster membership
Contrast = casual gardening

		Amateur enthusiastic gardening		Green fingered gardening		Hands off gardening		High tech enthusiastic gardening		Nothing to water	
		b	sig	b	sig	b	sig	b	sig	b	sig
Sum of environmental actions		0.078	c	0.048	a	– 0.018		– 0.003		– 0.032	a
Accommodation	Semi-detached (detached)	– 0.347		– 0.129		0.146		0.216		0.013	
	Terraced	– 0.999	a	– 0.773	a	0.187		– 0.212		0.132	
	Flat/maisonette	– 1.351		– 0.204		– 0.459		– 0.691		1.190	c
	Other	– 12.937		– 14.520		– 16.139		– 14.445		– 0.420	
N rooms	5 (<5)	– 0.912		0.238		– 0.189		0.983	a	0.310	
	6	– 0.030		0.745		– 0.500		0.909	a	0.206	
	7	0.230		0.897		– 0.288		1.192	b	0.082	
	8	– 0.345		0.803		– 0.280		1.239	b	0.090	
	>8	– 0.191		0.701		– 0.388		1.437	c	0.034	
Tenure	Rent from council (own)	– 0.067		– 0.451		– 0.042		– 0.196		0.261	
	Social rent	– 0.404		– 0.538		0.197		– 0.436		0.613	a
	Private rent/other	– 1.818		0.040		0.727	b	0.045		1.094	c
Cars	1 (None)	0.288		0.185		– 0.021		0.075		– 0.299	
	>1	1.103	a	– 0.236		0.212		0.471		– 0.446	
N children	1 (0)	0.873		– 0.809		0.290		– 0.523		0.084	
	>1	0.549		– 0.078		0.196		– 0.438		– 0.144	
N earners	1 (0)	– 1.241	a	– 0.527		– 0.370		– 0.298		– 0.479	
	2	– 0.283		– 0.136		– 0.146		– 0.358		– 0.512	
	3	0.146		– 0.536		0.483		– 0.306		– 0.221	
N persons	2 (1)	– 0.720		0.250		– 0.648	a	0.129		– 0.459	
	3	– 0.781		0.017		– 0.369		0.123		– 0.468	
	4	– 1.792	a	– 0.033		– 0.750		0.040		– 0.353	
	>4	– 15.263		– 0.230		– 0.793		0.444		0.106	
Age of HRP	25–34 (16–24)	0.352		1.323		– 0.145		– 0.558		– 0.140	
	35–44	0.176		1.617		– 0.564		– 0.388		– 0.277	
	45–54	0.239		1.705		– 0.472		– 0.423		– 0.052	
	55–64	0.805		1.480		– 0.523		0.147		– 0.269	
	65–74	0.356		1.899		– 0.325		– 0.508		– 1.074	b
	>74	– 0.108		1.687		– 0.481		– 0.275		– 1.524	c
Gender	Male (female)	– 0.229		0.456		– 0.072		0.091		– 0.192	
Limiting long term illness	Present (not)	0.478		– 0.168		0.209		0.002		0.060	
Ethnicity	HRP non-white (white)	– 0.864		0.052		0.631	a	0.521		1.162	c
Constant		– 2.856	a	– 4.553	b	1.300		– 0.964		2.034	b

$N = 1714$.
Pseudo r sq = 0.147.
Results statistically significant at: [a]5% level; [b]1% level; [c] > 0.1% level.

in Pullinger *et al.* (2013). For the current purposes, it is sufficient to say that these represent different ways in which personal washing and laundry cleaning are achieved, with potential water use implications. The differences in the variants of these practices which they perform are indicative of the substantial variation in how water is used in the different practices even in average water using households.

This diversity can also be seen in Figure 1, which presents a bubble plot of the scores of these respondents for the different elements of each practice (such as the

Table 3 | The variants of practice performed by five single occupancy households of close to average overall pcc of water

		Practice		
Household	**Water use, litres per day**	**Gardening**	**Washing**	**Laundry**
A	159.8	Casual gardening	[Not calculated - missing data]	Attentive clean laundering
B	143.7	Casual gardening	Simple daily showering	On-demand outsourcing
C	148.4	Hands-off gardening	Attentive cleaning	Simple home laundering
D	165.7	High tech gardening	Simple daily showering	On-demand outsourcing
E	148.6	Hands-off gardening	Simple daily showering	Simple home laundering

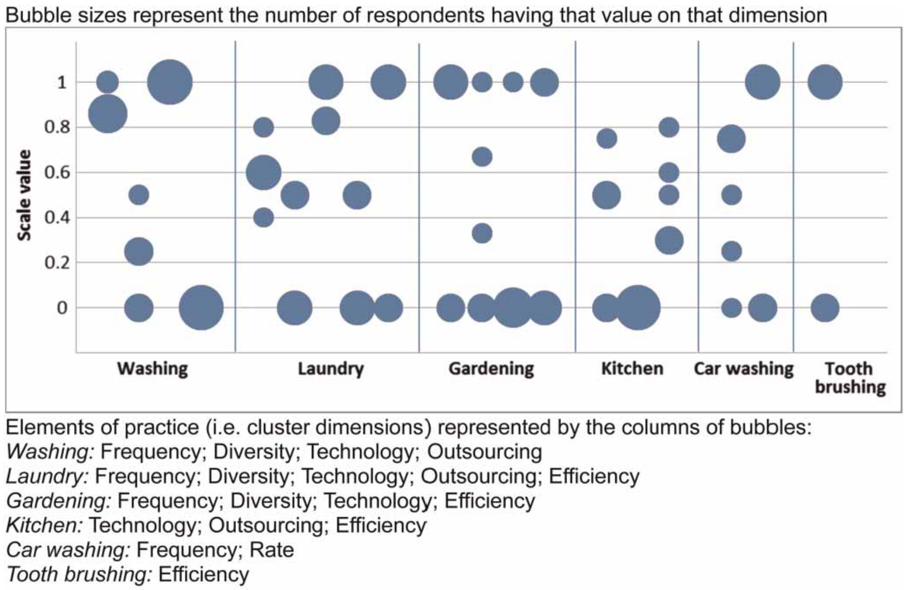

Figure 1 | Bubble plot of scores for the different elements/dimensions of water using practice performed by five single occupancy households of close to average overall pcc of water.

frequency of performance, the technology used, and how many outsourced services they use relating to the practice) on a standardised 0 to 1 scale. For many of the elements, there is substantial variation in the values for these five respondents, indicating again that there is large diversity between them within each of their water using practices, for each of the constituent elements.

As we have already seen, sociodemographic variables only weakly predict which variant of a practice a person will perform, so these results imply that forecasting future water use based on sociodemographic changes, which assume everyone in a particular sociodemographic group will change in the same way, is unlikely to produce accurate results, as each variant of each practice is likely to change in diverse ways over time.

DISCUSSION AND CONCLUSION

The results provide some evidence for the added value of quantitatively describing practices for understanding how people are currently using water, an important step in predicting how this might change in future or could be influenced. The approach is therefore of potential use for practitioners involved in forecasting future household water demand or in designing interventions to attempt to manage that demand. Some possible avenues of application in these areas are described below.

In terms of the added understanding, such practices research can provide with respect to household water demand, even micro-component monitoring of, say outdoor taps for example, would not be able to distinguish between those who have nothing to water in their garden and those who do but do not water it, or those who water using recycled water or rainwater harvesting. Equally, it would not be possible to distinguish between those who use water from their outdoor taps for watering their garden or for washing their car. Each of these could clearly respond to quite different interventions and, furthermore, usage from two households currently using equal amounts of mains water outdoors might change in dramatically different ways in future because of the interaction of these current practices with new technologies, environments, social norms and personal life situations. Similar considerations apply to other areas of water use in the home. This may help to explain why current approaches to targeting interventions might well underperform, as will conventional linear modelling approaches to forecasting future water use based on current pcc data and sociodemographic variables. This holds whether or not practices data, with sufficient refinement of the methods presented here, can be used to predict current pcc in terms of litres, as it demonstrates the diversity in *how* water is being used and hence the likely differing future trajectories of even 'average' households in response to changing conditions and interventions.

More specifically looking at garden water use, it is notable how many households do not water their gardens, and also how many only use jugs or watering cans to water their gardens: neither group would be directly affected by the hose pipe bans commonly implemented in periods of drought, although the imposition of a ban might serve to raise broad awareness of the importance of using less water, leading to indirect effects on litres used. Garden watering also overlaps with other substantial environmental issues, such as the potential beneficial effects of planting native species or having wild areas for biodiversity, or growing food at home, potentially reducing food miles. Trade-offs between agendas may then exist: encouraging reduced water use per se might not be the best goal (although perhaps reducing mains water use for gardening, in favour of other sources such as rainwater harvesting, could be).

The results also highlight the difficulties in designing interventions targeted at groups of households. On the one hand, if an approach of targeting interventions at particular variants of a given practice is adopted, a question arises about how to identify which households should be targeted by particular interventions, given that neither standard sociodemographics nor environmental actions are good predictors of how they will perform water using practices such as gardening. On the other hand, the approach also highlights the diverse, distributed influences on individual water usage, with wider factors such as social norms and meanings, and infrastructure, shaping and constraining individual or collective actions. Thus interventions could well be envisioned that target sources of constructed demand other than the individual household, such as technology providers, garden centres, and marketing and other channels of social norm diffusion, to encourage people to adopt more sustainable gardening practices.

The implication of the approach for water demand forecasting meanwhile is that pcc, and aggregate demand, cannot be predicted by extrapolating past pcc trends with a linear equation. Even 'average' water using households are demonstrably very diverse in how they use water, and each is likely to change their practices in complex non-linear ways as a result of changes at multiple interacting scales, of which household sociodemographic characteristics and preferences and values are only part. The practices approach does not directly produce more 'realistic' numbers for predicting future water use to inform modelling of the water supply and demand system, but it has the potential to help imagine how water using practices might change under different scenarios and what might be done to influence that, thus providing a valuable addition to future scenario modelling.

The results highlight certain limitations of the approach taken here, which in turn point the way to future development of the approach to increase its value further for both demand forecasting and interventions. For predicting water use based on practices, clearly one limitation of this research was that for only 73 cases to date were we able to link water meter data to the survey responses. Even then, this is still only total daily household water use averaged over a period of months, based on billing data: future studies would clearly and crucially require the linkage of micro-component monitoring on a fine-grained temporal basis (e.g. hourly at least) to studies of practices. This would also need to include multiple household members where homes are shared. In this vein we would point towards the recent Energy Saving Trust/ DECC/DEFRA research report on energy monitoring studies combining 'micro-component' energy measurement with surveys and 'use diaries' (Owen 2012). In the case of gardening, data on various other factors which are likely to substantially affect both practices and water use would also be helpful to collect, such as garden size, soil type and type of plants. The practical difficulties in collecting reliable data on such factors, and the fact this was not a central research aim of this project, meant that we omitted this from the current research. Linking such a practices survey with micro-component water usage data would allow finer estimates of how variants of practices shape and predict water use than could be achieved in this project with the small number of cases and a very crude measure of water use, i.e. household daily usage averaged over a period of months drawn from billing data.

This would also allow an investigation of the potential use of widespread 'smart meter' usage in households to support the more effective targeting of household-level interventions, given that variants of practice cannot be predicted well based on standard sociodemographics. If temporal water use profiles from such metering can be used to predict the variants of practices that a household follows then this could allow fine-grained, semi-automatic tailoring and targeting of household level interventions on a per customer basis. The sociological understanding of practices within the home that lead to the observed water consumption could potentially contribute to increasing the effectiveness of automated feedback provided to households through in-home display technologies (Strengers 2011), while such per customer tailoring of feedback would also remove the need to try to classify (or miss-classify) customers into 'actionable groups' at all, since each would appear to both themselves and the water provider as a 'market of one'.

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