Domestic Water Conservation: A Survey Assessing Practices in Vancouver Residents

Carter Bilawchuk, Louis Monaghan, Luc Lamont-Caputo, Victor Wong

University of British Columbia

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Group H2Low: Carter Bilawchuk, Luc Lamont-Caputo, Louis Monaghan, Victor Wong

Executive Summary

We conducted a study to investigate the following research question pertaining to water conservation in Vancouver. “Among different water conservation actions, what are Vancouver resident’s opinions on which practices they believe to be most effective at conserving water? What is their perceived costliness of implementing such water saving practices? What is their current usage of these practices and what their level of willingness adopt practices?” An online survey collected information on these questions from residents of Vancouver. Statistical analyses found that among all ten water conservation actions people did not rate them as statistically significantly in terms of effectiveness. Significant differences were found for the other three variables with perceived cost, current usage and willingness to implement showing statistical significance. Turning off the tap while brushing your teeth was rated as least costly, as well as most currently used and most willing to adopt. We found correlations among the questions. Most relevant are a strong positive correlation between current usage and willingness to adopt, as well as a negative correlation between costliness and willingness to adopt.

Research Question and Hypotheses

Among different water conservation actions, what are Vancouver resident’s opinions on which practices they believe to be most effective at conserving water? What is their perceived costliness of implementing such water saving practices? What is their current usage of these practices and what is their level of willingness adopt practices?

The different water conservation actions are one condition and the four questions pertaining to those actions is a second condition. We hypothesize that the mean scores of each level within the Actions condition will be unequal and the mean scores of each level within the Questions condition will be unequal. We hypothesize that there exist an interaction between Actions and Questions. The null hypothesis is that mean scores of each level within the Action and Question conditions are all equal and no interaction exists. We further hypothesize that correlations exist among the 4 questions with a null hypothesis that no correlations exist among the 4 questions.

Participants

Participants were 28 male and 14 female residents ($\bar{x}_{age} = 32.70$) from Greater Vancouver. Median annual income of participants was $50000-79000. The most reported dwelling type was apartments/condos (41% of responses). 93% of

participants report having post secondary education. Recruitment was by advertising the survey online (see Procedure).

Conditions

To gather information, we issued a 2-factor survey. The first factor is a set of water conservation Actions, which contains 10 levels, each being a single domestic water conservation practice (Table 1). The second factor is a set of Questions that pertain to each level of the first factor. The second factor has four levels: 1. How effective do respondents think the Action is? 2. How expensive do respondents think implementation of the Action will be? 3. How often do respondents implement the Action? 4. How willing are respondents to adopt the Action?

Measures

We constructed a custom questionnaire consisting of 2 parts. Part 1 is composed of 10 water conservation Actions (Table 1). Our 10 Actions are adopted from Attari's (2014) study on the perception of water use. Attari (2014) asked 1020 US citizens an open answer question: "What is the single most effective thing one can do to conserve water in the household?" and compiled a frequency list of all responses. We adopted the top 10 relevant responses from this list for use in our questionnaire, as we believe these items are a realistic representation of water saving methods practiced in a typical North American household. For each Action there are 4 questions (assigned by our client) asking the user to rank, on a 7-point Likert scale, the effectiveness of that action, the expense of that action to implement, how frequently they use the action, and their willingness adopt that action. Part 2 asked the user for demographic data (age, gender, education, income, and dwelling type).

Procedure

The online survey was created in and hosted by UBC Survey Tool. The survey was advertised to Greater Vancouver residents on the UBC Connect website, the classified site Craigslist, the social media site Facebook, the Water Day 2016 website, and through word-of-mouth of the investigators. The collection time period was the month of March, 2016. After the collection period, data was exported into Excel where descriptive statistics were calculated. Data was exported into R for ANOVA, Tukey’s HSD, and Pearson R calculations.

Results

Mean "effectiveness", "expensive", "usage", "willingness" scores are plotted in Figures 1-4 respectively. To test for main effects and interaction, we conducted a 2-way (10x4) repeated measures ANOVA with two within subjects measures: Questions and Actions. Hypotheses were supported as the main effect of Action was significant $F(9, 1595) = 4.042$, $p < 0.001$ as was the effect of Question $F(3, 1595) = 15.952$, $p <$

0.001. Of most interest, the interaction (Action x Question) was also significant $F(27, 1595) = 5.141$, $p < 0.001$.

To determine what parts of the interaction are significant, we followed with more focused tests. We calculated one-way ANOVA on each of the four possible Questions-Actions sets. Expense-Actions ($F(9, 399) = 12.16$, $p < 0.001$), Usage-Actions ($F(9, 399) = 4.522$, $p < 0.001$), and Willingness-Actions ($F(9, 399) = 3.688$, $p < 0.001$) all showed reliable differences at 0.05 level of significance, only Effectiveness-Actions ($F(9, 398) = 1.067$, $p = 0.386$) did not. Post-hoc Tukey's test was run on each Expense-Actions, Usage-Actions, Willingness-Actions to determine, within each factor, where the pair means significantly differed. All pairwise comparisons within Expense-Actions, Usage-Actions, and Willingness-Actions are found in Tables 2-4 respectively with significant comparisons marked with asterisks.

We performed Pearson R correlations on all level combinations within the Question condition. Complete r and p-values are found in Table 5. Correlation hypotheses found support with Effectiveness-usage ($r = 0.136$, $p = 0.005$), Effective-willing ($r = 0.182$, $p < 0.001$), Expense-usage ($r = -0.250$, $p < 0.001$), Expense-willing ($r = -0.275$, $p < 0.001$), and Usage-willing ($r = 0.703$, $p < 0.001$) all significant at $\alpha = 0.05$. Effective-expense ($r = 0.093$, $p = 0.059$) was the single correlation not significant at $\alpha = 0.05$.

Discussion

Our results show that Effectiveness scores are not statistically different among the 10 Actions. This finding suggests that although people recognize Actions differ in effectiveness, as some Actions score higher than others (Fig 1.), statistically, no single Action outperforms another Action in terms of effectiveness rating. Research from the Environmental Protection Agency (EPA) (2005), however, showed that some actions (e.g., retrofit toilet) vastly outperform other actions in water saving effectiveness. Additionally, respondent's effectiveness ratings seem to under or overestimate the true effectiveness of Actions. For example, respondents rated "watering the lawn less" as most effective action. EPA (2005) research showed that retrofitting toilets provides the greatest water savings, accounting for 71% savings in household water use. This under and overestimation of effectiveness on Actions is consistent with recent research on perceptions in water use (Attari, 2014). A lack of information on the true quantities of water used and saved by each Action could explain why respondents are unable to accurately assess that some Actions are more efficient than others. Attari (2014) suggests when people estimate water efficiency they select a reference action as a starting point and adjust estimates around it, but estimates insufficiently, erring in under and overestimation.

In contrast to Effectiveness, our results on Expense scores showed a reliable difference among the 10 Actions. Statistically, respondents show they believe that some Actions are more expensive than others. Respondents appear to think carefully about expense as evident by 67% (30/45) of pair wise showing significance (Table 2). Respondents appear to be assigning many of the Actions into discrete expense categories analogous to discrete items with different prices in a market. One explanation for this finer evaluation is, unlike Effectiveness, Expense has a shared

normalized reference metric in the form of currency, which may facilitate people to perceive nuance in Expense among the actions. It would be interesting for future studies to investigate the shared metric idea. If it is valid, we predict people to be much more accurate at estimating the true price of Actions than estimating the true quantities of water saved by Actions.

Our results for Usage and Willingness also showed a statistically reliable difference among the 10 Actions. Differing from Expense, post hoc analysis of Usage and Willingness showed significant differences primarily among two actions: Brushing teeth with the tap off (OffTapTeeth) and doing full loads of laundry (FullWasher) (Table 3, Table 4). These results suggest that respondents are using and are willing to employ these two actions more so than almost any other action. Why should this be the case? One idea is simple exposure. To bring awareness to water conservation many forms of media provide a list of water conservation methods. If media consistently contains actions OffTapTeeth and FullWasher the constant exposure may elicit usage or a willingness to try them. To test this idea, future studies could examine water conservation outreach media and check if a relationship exists between frequently advertised actions and greater usage and adoption. A possible mechanism, we think, for how OffTapTeeth is reported significantly across the board under Usage (Table 3) is a "rider" idea. What brushing ones teeth and doing laundry have in common is they are routine activities that mostly cannot be avoided. If a small behaviour modification (e.g., turn tap off) can be appended (via media exposure) to an unavoidable activity (e.g., teeth must be brushed) that does not change the quality of that activity (e.g., brushing is the same with the tap on or off) but brings along a side-effect (e.g., saves water), that side-effect will "ride" along whenever the unavoidable behaviour is performed. The idea is analogous to a rider attached to bill in legislative procedures. If people become aware of the water saving side-effect that is attached to a routine activity, they can report they use that water saving measure the most as they perform that routine activity the most in their daily lives.

Correlations were performed on all combinations of Effectiveness, Expense, Usage, and Willingness (Table 5). There was no significant correlation between Effectiveness-expense. This is not surprising given that statistically respondents evaluated Actions as all equally effective; thus, for a single unit change in Expense there is effectively no change in effectiveness. Effectiveness-usage and Effectiveness-willing both showed small positive significant correlations that explain 1.8% and 3.3% of the variability of their respective scores (Table 5). This suggest that Effectiveness is not a large factor in explaining the differences in scores in usage and willingness, which makes sense given that Effectiveness is seen not to differ greatly across actions (Fig 1.). As consistent with a common sense expectation both Expense-usage and Expense-willing showed significant negative correlations. People report using Actions they deem as expensive less often and are less willing to adopt them.

Of most interesting to water conservationists is the strong significant positive correlation between Usage-willing (Table 5). This finding suggest that what people are presently doing they are also willing to do in the future. For conservationists this can represent permanence in sustainable behaviour. Looking at it in the reverse direction, what people are willing to do in the future, they are doing now. This pattern is akin to a pledge or promise, which suggests that if people rate a sustainable behaviour as

something they are willing to do, they are likely to follow through with it. Finally, even if the correlation is explained by a third factor, like the aforementioned exposure, this is still good news for conservationist, as it suggests that outreach and advertising has an effect on sustainable behaviour.

The findings of this study are restricted by its limitations. Firstly, our small size means we may not have had the power to detect effects that are present in the Vancouver population. For example, Residents of Vancouver may believe water conservation actions vary in their effectiveness but our survey may not have had the power to detect that. Secondly, biases in sampling are present due to the online recruitment that was employed. By recruiting online, our selection is biased towards individuals that spend more time on the internet (e.g., younger people) and towards those in the social circles of the researchers (e.g., students). Thirdly, the actions in the study are not equally relevant for all residents. Watering the lawn less and acquiring water saving plants has limited relevance for the 41% of respondents living in apartments. Similarly, some respondents may not have washing machines or dishwashers in their place of residence. Consequently, the conclusions of this study may be limited in their pertinence for the target population of Vancouver residents.

Recommendations

The conclusions drawn from this study can aid the client's SEEDS sustainability program in a variety of ways. Residents of Vancouver seem to show that they believe that different water conservation actions are equally as effective at saving water. People may lack knowledge that different water conservation practices vary in their capacity to save water. In addition to education and outreach awareness programs, to close this information gap, standard water saving unit could be introduced. Similar to certified organic labelling, this unit could be shown conspicuously only on products and services that meet rigorous criterion for true water savings. This could help people make informed decisions and garner trust regarding water saving services and products. Another approach to help the public is a slight change to outreach materials. Frequently water saving tips is presented in long lists with less efficient and more efficient actions presented together. If people think one action is just as good as another, they are as likely to select the less efficient action as the efficient one. It may be better practice to present people with filtered action lists that contain actions of the highest efficiency.

The study found an importance of expense when it comes to conserving water. Actions perceived as expensive to implement were less likely to be currently employed by individuals and people were less willing to employ them in the future. People respond to costs, so cost saving measures built into water saving practices such as subsidies and tax deductions could encourage adoption of a water saving action. Advertising on water saving devices (e.g., taps, washing machines, dishwasher, etc.) could include, for example, the dollar value saved over 5 years of average use, relative to a non-water saving device.

People were found to be more willing to use water conserving actions that they are currently employing. This indicates a long-term stability of water saving habits and behaviours. Programs like public workshops that present novel water saving methods

regularly could encourage the adoption new water saving actions by people. Pledges can be a useful exercise as well, as there is the correlation in what they are most willing to do, they currently employ.

Research into differences between water-saving methods is made difficult by the diversity of water use in the home. Future research could look at specific sub-populations to gain a better insight into factors influencing how residents of Vancouver save water. For example, such studies could analyse differences in persons who pay for their water and those that do not. Understanding people's perceptions of different water conservation practices will contribute to the effectiveness of outreach programs to the residents of Vancouver, enabling us to conserve this precious resource.

Appendix

Conversations with Clients

Originally presented with three research questions (What do people in Vancouver believe to be the most effective water conservation practices for individuals at home and at work? What actions are they currently doing? What action would they be willing to adopt?) pertaining to both domestic and workplace water conservation practices, our group decided to focus on domestic only, as workplace conservation efforts vary far too much across different fields of work. When discussing this change with our clients we also decided it would be beneficial to add a question regarding the cost of implementing each water conservation method. This new question in addition to the three originals, form our research question for this study.

Sample size: Perhaps just unlucky, but for a week after the survey went live, there was only a single response. Perhaps with more time to cancel out this slump, we could have accrued the suggested minimum N = 50 or more.

Minor concern: Very late in the project (March 31, 2016) we were asked to add a hypothesis regarding correlations. Hypothesis was added, but since quite late, insufficient time to verify if the addition was added correctly.

References

Attari, S. Z. (2014). Perceptions of water use. *Proceedings of the National Academy of Sciences*, *111*(14), 5129–5134. http://doi.org/10.1073/pnas.1316402111

Environmental Protection Agency (2005). Water and Energy Savings from High Efficiency Fixtures and Appliances in Single Family Homes. Retrieved from: http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/residential/showers/Aquacraft%282005%29EPA- Single-Family-Retrofit-Studies-Combined-Report.pdf. Accessed April 7, 2016.

Tables and Figures

Shorter or fewer showers
Turn off water while applying soap/shampoo
Turn off water while brushing teeth
Do full loads of laundry
Water lawn less
Check for leaks and repair them
Flush less
Switch to low flow shower heads
Switch to water efficient toilet
Switch to water efficient washer

Table 1. List of the 10 water saving Action items used in the survey.

	FlushLess	WaterLawnLess	RepairLeak	ShowerLess	OffWaterSoap	SwitchShower	SwitchToilet	SwitchWasher	OffTapTeeth
WaterLawnLess	<0.05*	-	-	-	-	-	-	-	-
FixLeak	<0.001***	0.31	-	-	-	-	-	-	-
ShowerLess	0.3409	<0.001***	<0.001***	-	-	-	-	-	-
OffWaterSoap	0.6479	<0.001***	<0.001***	1	-	-	-	-	-
SwitchShower	<0.001***	0.7923	1	<0.001***	<0.001***	-	-	-	-
SwitchToilet	<0.001***	<0.001***	0.0616	<0.001***	<0.001***	< 0.01**	-	-	-
SwitchWasher	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.3997	-	-
OffTapTeeth	0.0718	<0.001***	<0.001***	1	1	<0.001***	<0.001***	<0.001***	-
FullWasher	1	< 0.01**	<0.001***	0.6726	1	<0.001***	<0.001***	<0.001***	0.2303

Table 2. Post hoc Tukey HSD results of Expense scores among the ten Actions. All significant pair wise differences in means comparisons are indicated by asterisk(s), *p<0.05, **p<0.01, ***p<0.001

	FlushLess	WaterLawnLess	RepairLeak	ShowerLess	OffWaterSoap	SwitchShower	SwitchToilet	SwitchWasher	OffTapTeeth
WaterLawnLess	1	-	-	-	-	-	-	-	-
FixLeak	1	1	-	-	-	-	-	-	-
ShowerLess	1	1	1	-	-	-	-	-	-
OffWaterSoap	1	0.41366	1	1	-	-	-	-	-
SwitchShower	1	0.11767	0.98847	0.41366	1	-	-	-	-
SwitchToilet	1	0.24483	1	0.73346	1	1	-	-	-
SwitchWasher	1	0.31999	1	0.911	1	1	1	-	-
OffTapTeeth	<0.001***	< 0.01**	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	-
FullWasher	< 0.01**	0.41366	<0.05*	0.11767	<0.001***	<0.001***	<0.001***	<0.001***	1

Table 3. Post hoc Tukey HSD results of Usage scores among the ten Actions. All significant pair wise differences in means comparisons are indicated by asterisk(s), *p<0.05, **p<0.01, ***p<0.001

	FlushLess	WaterLawnLess	RepairLeak	ShowerLess	OffWaterSoap	SwitchShower	SwitchToilet	SwitchWasher	OffTapTeeth
WaterLawnLess	1	-	-	-	-	-	-	-	-
FixLeak	0.4072	1	-	-	-	-	-	-	-
ShowerLess	1	1	1	-	-	-	-	-	-
OffWaterSoap	1	1	0.12884	0.60698	-	-	-	-	-
SwitchShower	1	1	0.09586	0.50098	1	-	-	-	-
SwitchToilet	1	1	0.5635	1	1	1	-	-	-
SwitchWasher	1	0.4072	<0.01**	0.06125	1	1	1	-	-
OffTapTeeth	<0.001***	< 0.01**	0.3651	0.06125	< 0.001***	< 0.001***	< 0.001***	< 0.001***	-
FullWasher	< 0.05*	0.66408	1	1	< 0.01**	< 0.01**	0.05534	< 0.001***	1

Table 4. Post hoc Tukey HSD results of Willingness scores among the ten Actions. All significant pair wise differences in means comparisons are indicated by asterisk(s), *p<0.05, **p<0.01, ***p<0.001

Correlation	r	p
Effective-expense	0.093	0.059
Effective-usage	0.136 (0.018)	0.005
Effective-willing	0.182 (0.033)	< 0.001
Expense-usage	-0.250 (0.062)	< 0.001
Expense-willing	-0.275 (0.076)	< 0.001
Usage-willing	0.703 (0.494)	< 0.001

Table 5. r and p-values of all Question combinations (repeats and self correlations omitted). Parentheses are r^2. All correlations except Effective-expense are reliable at 0.05 level of significance.

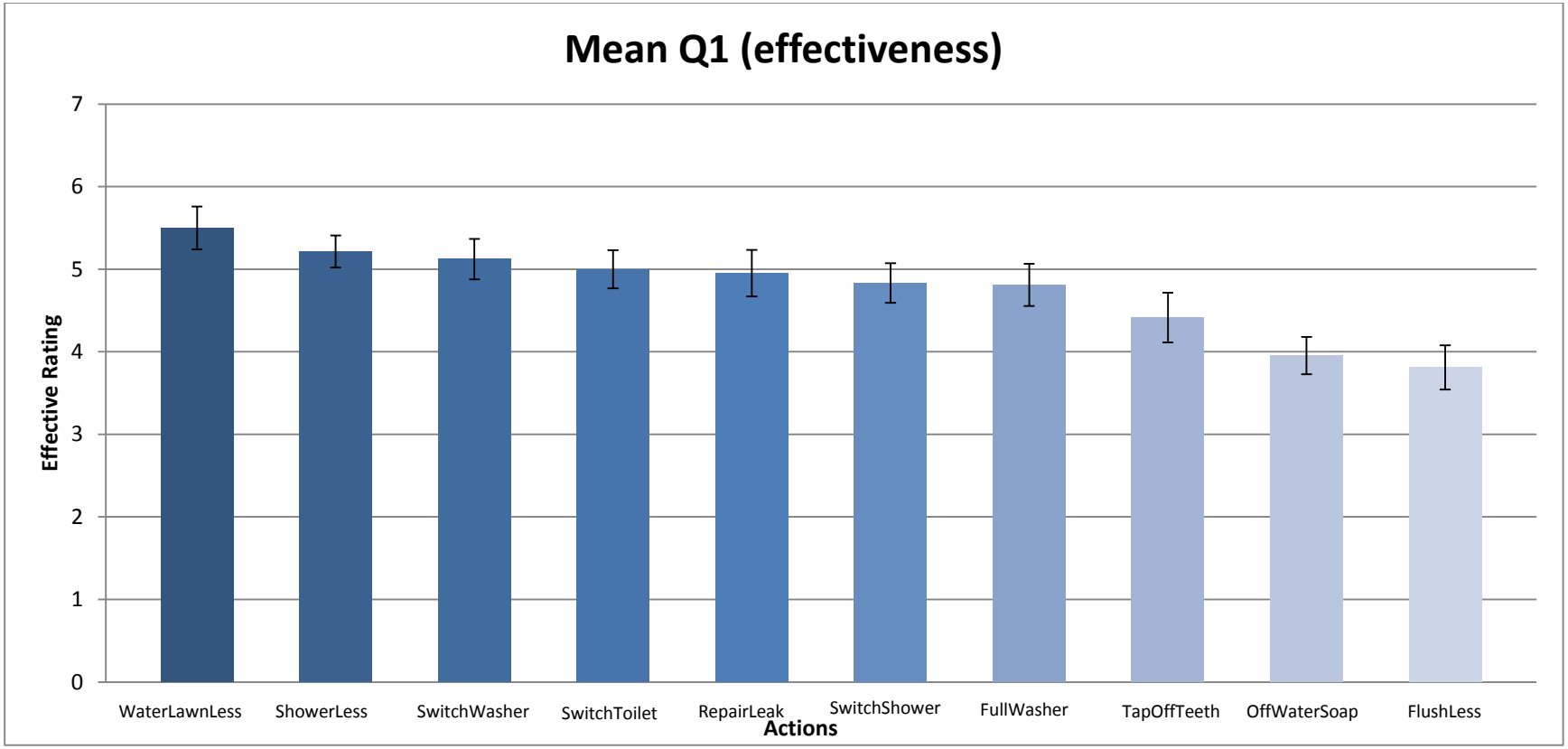

Figure 1. Mean "effectiveness" scores for each Action. Error bars reflect ±1SEM. Effectiveness showed no reliable differences at the 0.05 level of significance $F(9, 398) = 1.067$, $p = 0.386$

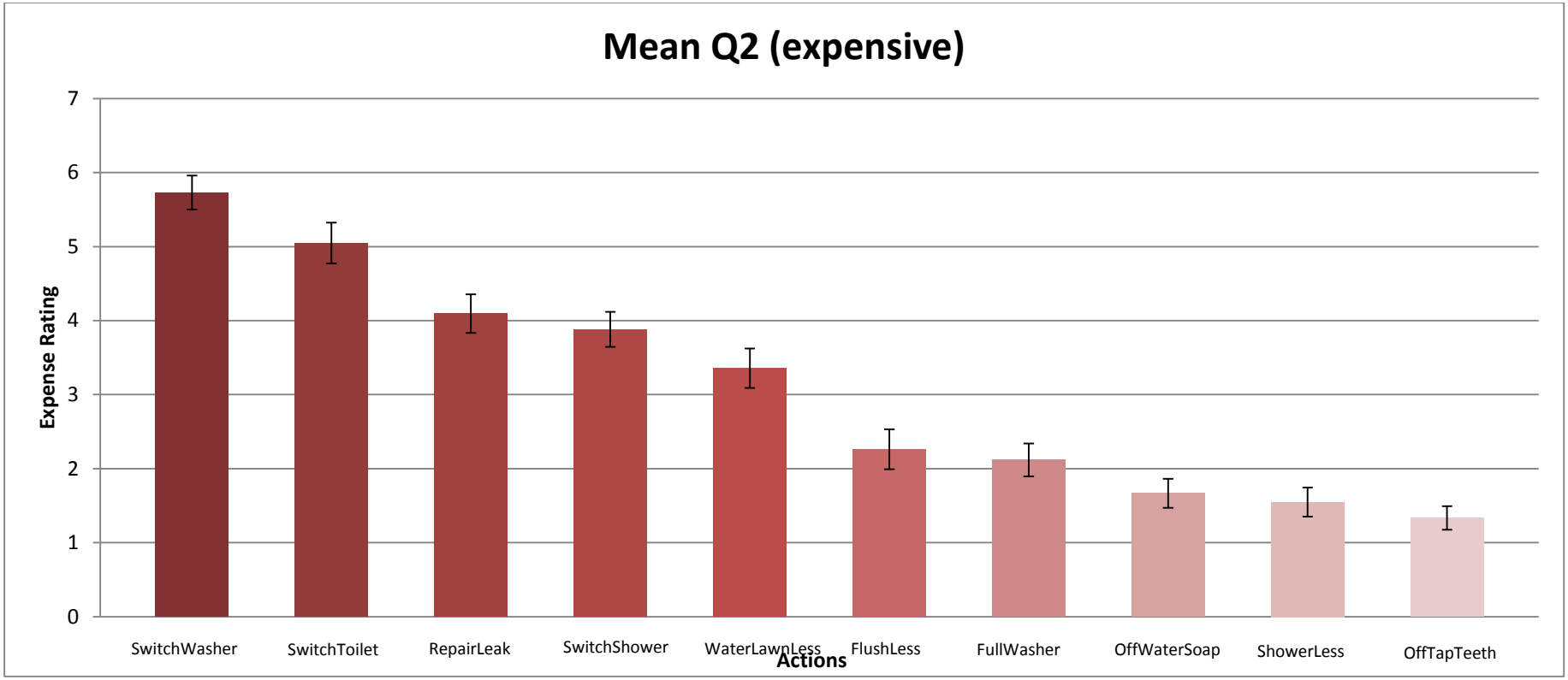

Figure 2. Mean "expensive" scores for each Action. Error bars reflect ±1SEM. Expensive showed reliable differences at the 0.05 level of significance $F(9, 399) = 12.16$, $p < 0.001$

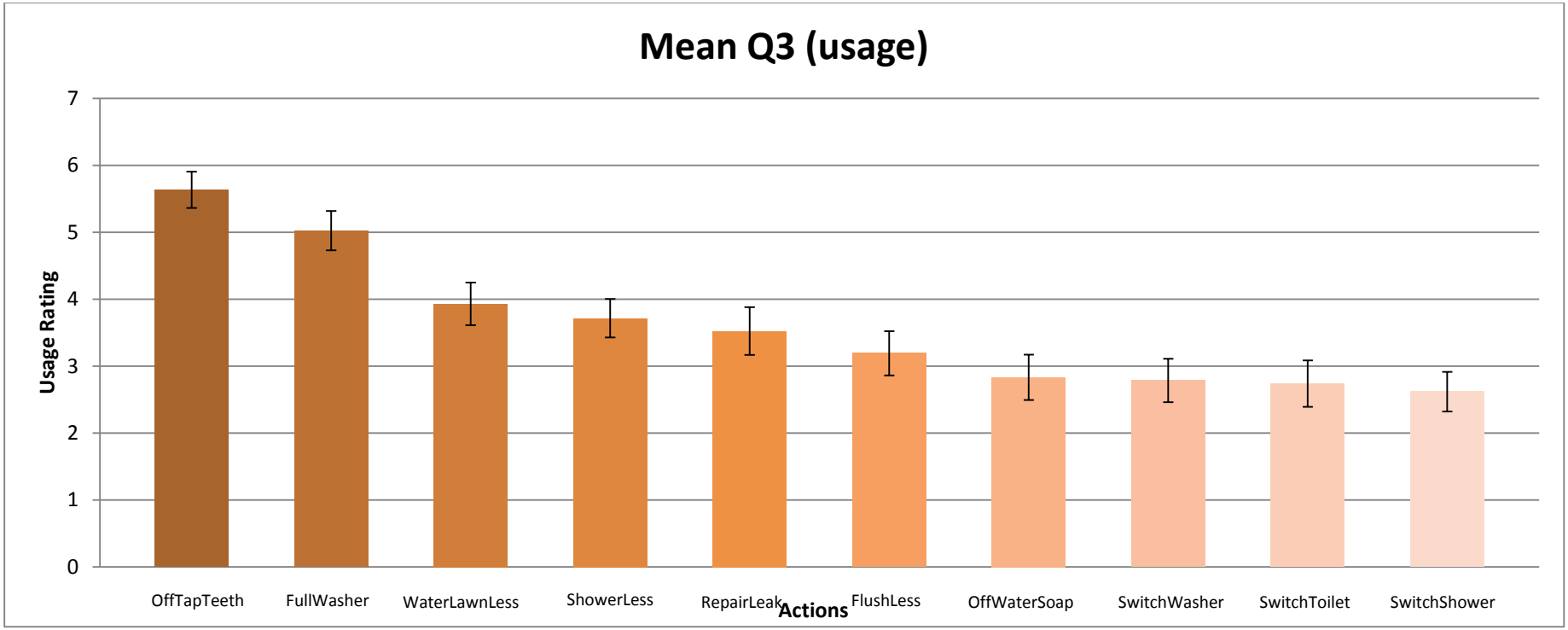

Figure 3. Mean "usage" scores for each Action. Error bars reflect ±1SEM. Usage showed reliable differences at the 0.05 level of significance $F(9, 399) = 4.522$, $p < 0.001$

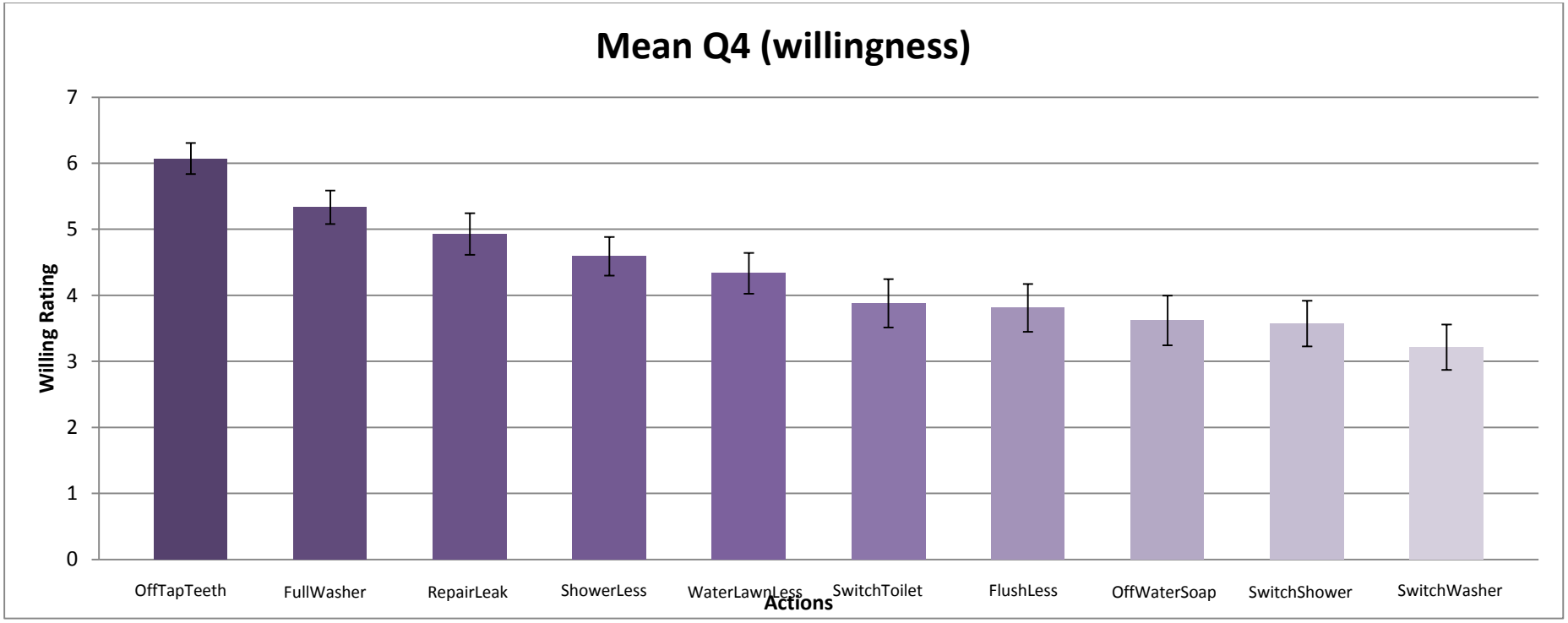

Figure 4. Mean "willingness" scores for each Action. Error bars reflect ±1SEM. Willingness showed reliable differences at the 0.05 level of significance $F(9, 399) = 3.688$, $p < 0.001$