

# Curbing Resource Consumption Using Team-Based Feedback

## - Paper Printing in a Longitudinal Case Study -

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**Abstract.** This paper details a team-based feedback approach for reducing resource consumption. The approach uses paper printing within office environments as a case study. It communicates the print usage of each participant's team rather than the participant's individual print usage. Feedback is provided weekly via emails and contains normative information, along with eco-metrics and team-based comparative statistics. The approach was empirically evaluated to study the effectiveness of the feedback method. The experiment comprised of 16 people belonging to 4 teams with data on their print usage gathered over 58 weeks, using the first 30-35 weeks as a baseline. The study showed a significant reduction in individual printing with an average of 28%. The experiment confirms the underlying hypothesis that participants are persuaded to reduce their print usage in order to improve the overall printing behaviour of their teams. The research provides clear pathways for future research to qualitatively investigate our findings.

## 1 Introduction

Consumption of resources is a major concern from financial and environmental perspectives. Paper printing, electric heating and transportation are all examples of resource consumption related to everyday activities in normal business environments. Modern computing technologies and devices to track such resource consumption can intervene to curb wastage. However, proper intervention methods are yet to provide a significant impact [1]. There is a need to support such methods with theoretical and empirical studies involving users and consumers of resources.

Medland [2] devised a feedback-based intervention method to reduce wastage in paper printing. The method is based on providing staff in an office environment with their printing statistics. Within the approach, multiple feedback "flavours" were evaluated, ranging from traditional usage statistics, eco-metric printing statistics to comparative and competitive statistics. In this paper we build on this approach by using a team-based feedback method that leverages the membership of individuals in local teams with no individual performance being communicated.

The hypothesis is that by providing people with their team's resource consumption performance in relation to that of other local teams, a social incentive is created for individuals to improve their team's overall performance. We tested the hypothesis in an office environment for over a year, with paper printing as the particular instantiation of resource consumption. Our experiment includes 16 participants belonging to four teams. It compares the printing performance of participants during a baseline period before applying – or communicating intent to apply – the feedback method, with their performance after applying the method. Results show a statistically significant improvement in individual printing behaviour after applying the team-based feedback method confirming the tested hypothesis.

The rest of this paper is organised as follows. Section 2 reviews related work in the areas of persuasive technology, social norms and feedback-based pro-environmental behaviour. Section 3 describes the case study environment and the software architecture employed to implement the experiment and then details the research design. Section 4 presents the results, and Section 5 discusses these results in light of three themes. Section 6 concludes the paper with suggested prospects for future research.

## **2 Related Work**

### **2.1 Persuasive Technology**

Our research employs persuasive technologies that increase awareness of resource consumption providing pathways for restructuring behaviour. According to persuasive technology theorists such as Fogg [3, 4], "... a persuasive technology is fundamentally about learning to automate behaviour change" (p. 1). These technologies are designed to persuade those using them through a range of methods, particularly social influence, to change their behaviours by first changing their attitudes. Lockton et. al. [5] extend this definition by including situations, such as safety systems, where attitude change is not a precursor for behaviour change, and is in fact not a consideration. Beyond these considerations - and given our focus on teams in this research - Khaled et. al. [6] point to a need for consideration of collectivist versus individualist cultural dimensions. As technologies become more pervasive they also often need to persuade, if they are to assist us in our daily lives [7]. Speaking to this conclusion were researchers such as Davis [8] who considered the perceived usefulness and perceived ease of use of ICT as determinants for user acceptance of those technologies. What has become more obvious in the last decade is that as the uses and users of ICT expand, so do the expectations of the user experiences when using that technology [9].

### **2.2 Social Norms**

Our research takes advantage of social norms and the well-established roles they play in predicting behaviour [10, 11]. For the purposes of our research, social norms were divided into two types: descriptive and injunctive. *Descriptive* norms provide information on commonly accepted behaviours; the standard that people attempt to adhere to [10]. Deviant behaviour diverges from this norm and is often negatively perceived.

*Injunctive* norms are shaped by cultures, providing guidance on behaviours that are approved or disapproved of. Applying descriptive or injunctive normative information in isolation can cause reflexive results, such as causing outliers to converge, even when they are exemplars of the behaviour you wish to encourage. To counteract this “boomerang” effect, the descriptive and injunctive feedback should be applied in tandem, providing reinforcement for high-achievers, whilst communicating the need for change to underperformers [11, 12].

### **2.3 Feedback and Pro-environmental Behaviour**

Feedback is inherently information and is often available, and linked to, contextually relevant events [2]. We know that information provided at these moments - or at regular intervals - has attributes or qualities that aid in understanding, accessibility, and retention (such as being memorable or surprising) [13]. For most of the resources consumed as part of daily living, feedback in some form is available, though often fairly simplistically [14]. This simplicity leads to a common issue: translating the consumption data into readily accessible - and actionable - information for the individual [13]. More problematic still, even though some individuals understand their resource consumption, they do not take up relevant pro-environmental behaviours to reduce it [15]. In the setting for our research paper was a monitored and digitally recorded resource, despite this, the best estimates for the individual prior to our study was the visual assessment of the paper to be recycled. Our current research leverages these findings to provide regular accurate feedback in a persuasive manner for paper using a number of metrics.

## **3 User Study**

In order to study the effect of team-based feedback on individual consumption behaviour, we chose to set up an experiment to track printing practices in an office-based environment that natively has different working units operating as information-intensive semi-autonomous teams.

### **3.1 The Case Study Environment**

The experiment was conducted within the Digital Enterprise Research Institute (DERI) located in Galway, Ireland<sup>1</sup>. DERI is a research institute focusing on research activities in multiple aspects and applications of the Semantic Web [16]. As of November 2012, DERI employed about 130 staff. Staff can be grouped into: research interns, master and PhD students, post-doc researchers, research assistants, research fellows, senior research fellows, professors, technical staff, and administrative staff. Staff is divided among a set of about 20 organisational units. Each of the units conducts research in an aspect of the Semantic Web. A set of communal printers are dis-

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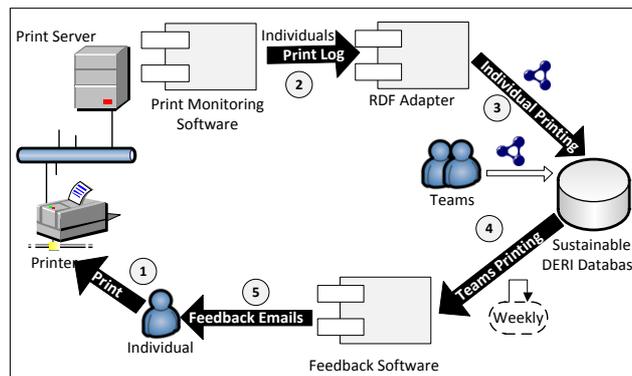
<sup>1</sup> <http://www.deri.ie/>

tributed around the DERI building. Reasons for printing in DERI are summarised in the following categories:

- Administrative printing by administrative and research staff.
- Printing research proposals, theses, academic and technical reports.
- Printing academic papers for internal review and reading purposes.

### 3.2 Print Monitoring

Printing is tracked in the DERI building using print monitoring software. The monitoring software installed on the main print server in DERI monitors the print queues of all the existing printers connected to the DERI network. It records each print job with various attributes such as date and time, and the number of printed sheets. This data gathering process is invisible to staff and some incidents occurred during our study demonstrating that participants were unaware of the data recording.



**Fig. 1.** Feedback cycle architecture.

The software can export detailed print logs for any date and time range. However, these logs do not associate staff with their business units or teams. As a proxy, we employed a graph database that uses the Semantic Web Resource Description Framework (RDF) [17]. It consolidates organisational and various sustainability-related entities in DERI in one place based on Linked Data principles [18]. It is regularly fed by various data collectors including an RDF adapter to print-monitoring software developed under the Sustainable DERI project [19]. The Sustainable DERI database can be queried using the Semantic Web SPARQL query language [20]. The Sustainable DERI Linked Dataspace is investigated in more details in [21] with a feedback scenario for cloud computing consumers in [22].

### 3.3 Feedback Software

The feedback software used for the experiment builds on previous work [2]. The feedback software is responsible for querying the Sustainable DERI database on a weekly basis in order to generate and send emails to individual participants. Email was chosen as the communication channel as it is deemed legitimate by all staff (where others such as instant messaging are not). Figure 1 illustrates the architecture used to generate and send the feedback emails.

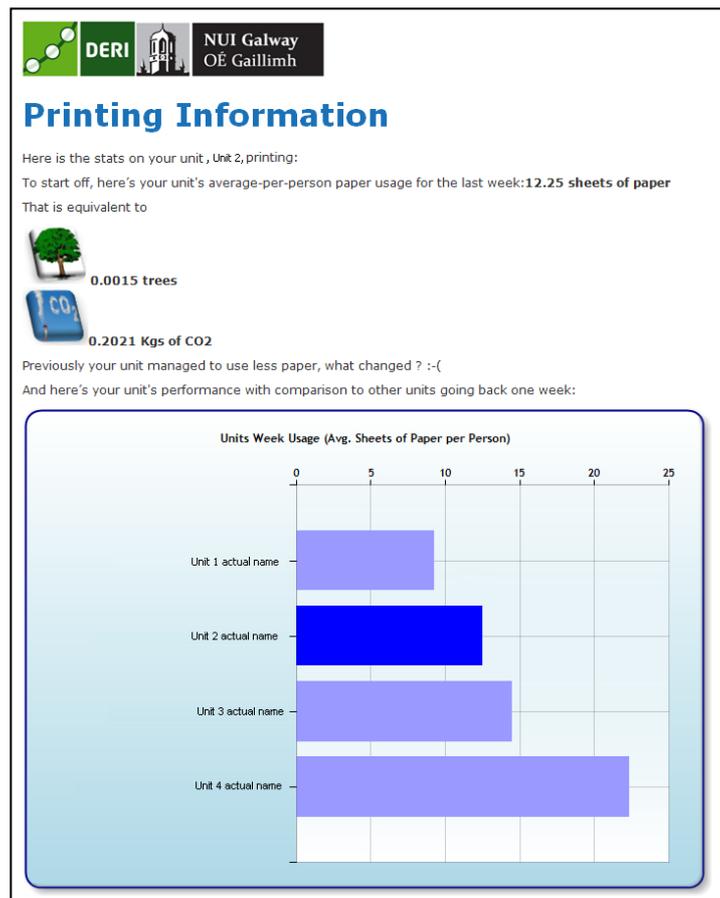


Fig. 2. An example feedback email.

The email sent includes three feedback methods to communicate the same information as a previous study [2] showed that multiple methods are needed to address the multiple feedback flavours that different staff would find persuasive for them. The feedback methods are described below. To facilitate this discussion, please refer to Figure 2 for a sample email.

- **Traditional statistics:** where the email states the number of pages printed by the person’s team averaged by person. E.g. “Here is your unit’s average-per-person paper usage for the last week: 12.25 sheets of paper.”
- **Eco-metric statistics:** where the number of sheets is converted to an estimated amount of trees or CO<sub>2</sub> emissions. E.g. “Your unit’s average-per-person printing for the last week is equivalent to 0.0015 trees and 0.2021 kg of CO<sub>2</sub>.”
- **Comparative statistics:** where a comparison is drawn on a week-to-week basis and a team-to-team basis. The comparative statistics target the use of descriptive and injunctive social norms [10, 11] in order to affect individual’s behaviour. E.g. “Previously your unit managed to use less paper, what changed? ☹️.” In this case injunctive normative information is the sad face, denoting that in your previous week you achieved lower paper consumption. Conversely, if your efforts are better than previously recorded, a smiling face is displayed. Another example is a chart that illustrates printing performance of the participant’s team in comparison with other participating teams during the previous week.

### 3.4 Experimental Setting

While more granular print usage is available for each participant, data was aggregated and displayed weekly. This time period forms the smallest temporal unit we deal with throughout our study. Gathering of printing data logs for all DERI members started in October 2010. Throughout the period until May 2011, no feedback emails were sent to any participants. Thus, this period forms the baseline for our study. After the end of the baseline period, team leaders were asked to participate and briefed informally. Thereafter, participants received feedback emails on a weekly basis. Participation in the experiment was voluntary. Ultimately a set of 16 members belonging to four different research units participated in the experiment as shown in Table 1. Participants started to receive feedback emails between weeks 31 and 35 of the study. Feedback emails continued to be sent until week 58 when the experiment ended.

**Table 1.** Participating members per teams (data anonymised).

Team	Members
Unit 1	Members 1, 2, 3,4
Unit 2	Members 5, 6, 7, 8, 9, 10
Unit 3	Members 11, 12, 13
Unit 4	Members 14, 15, 16

The main measure studied in our experiment is the total number of printed sheets of paper per person per week. The measure is evaluated using a before/after paired statistical test with baseline period as the “before” period, and the feedback period as the “after” period. However, variations might occur throughout the study in the overall printing behaviour in DERI due to project deliveries, proposal deadlines or a financial year end for example. Events such as these might cause an increase or decrease in printing by participants that is not resultant from the feedback itself, but

related to the impact of an external event. To explain this, let us assume that a person prints 10 sheets per week before applying the feedback method, and 7 sheets per week afterwards. It is not possible to safely state that there is a decrease in printing of 30% that is resultant from the feedback method. If DERI printing in general decreases from 1000 sheets per week before to 700 afterwards, then it is probable that an external variable has an effect on the amount printed. In order to isolate such external variables it was decided to use the person proportional printing over DERI printing every week. If a person prints 10 sheets in a week and DERI prints 1000 sheets during the same week, then the person proportional printing is said to be 1%.

## 4 Results

Our initial hypothesis was that participants would reduce their print usage in order to improve their team performance. This hypothesis would be confirmed if the print usage of each participant decreased significantly after applying the feedback method.

### 4.1 Individuals Level Printing Performance

Table 2 presents the weekly average printing proportions of participants for DERI as a whole. Printing data is sourced from two periods: the period before the feedback method was applied, and the period afterwards, until the end of our study.

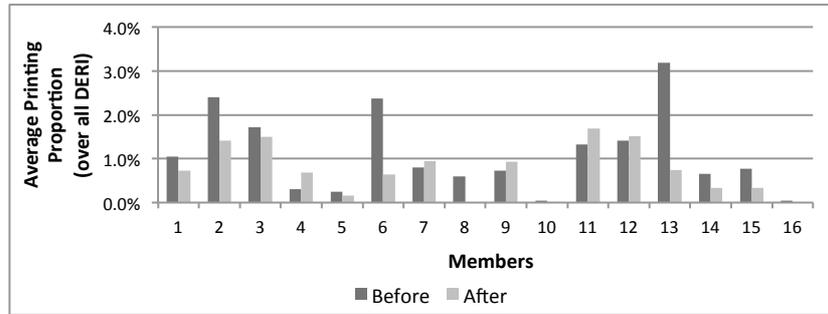
**Table 2.** Participant average weekly printing proportions for DER as a whole.

	Members							
	1	2	3	4	5	6	7	8
Before	1.05%	2.39%	1.72%	0.31%	0.24%	2.37%	0.80%	0.60%
After	0.73%	1.41%	1.50%	0.69%	0.16%	0.64%	0.95%	0.00%
	Members							
	9	10	11	12	13	14	15	16
Before	0.73%	0.04%	1.32%	1.41%	3.19%	0.65%	0.77%	0.04%
After	0.93%	0.01%	1.68%	1.52%	0.73%	0.33%	0.34%	0.00%

Figure 3 provides an alternative illustration of participant performance, comparing “before” and “after” pair-wise numbers. Figure 3 shows reductions in most participants printing after applying the feedback method. Table 2 shows that the average reduction is approximately 28% compared to printing before feedback was received. Nevertheless, five participants, namely 4, 7, 9, 11, and 12, show slight increases in proportional printing.

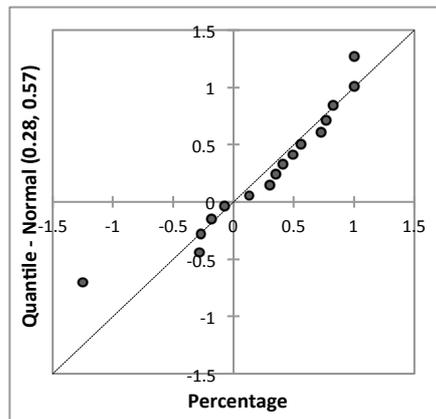
In order to infer if the feedback method did in fact cause a reduction in the average proportional printing, we performed a statistical test over two samples: before and after applying the feedback method. These two samples are in fact repeated measures of the same participant printing. Thus, a standard statistical paired t-test is suitable in this case [23] to test our hypothesis. The t-test is done over one sample that represents

the pair-wise differences between measurements in the two samples. Because the “difference” sample size in this experiment is  $16 < 30$ , the  $t$ -test cannot be done unless the “difference” sample follows a normal distribution.



**Fig. 3.** Participant printing performance before and after applying the feedback method.

In order to check normality of the “difference” sample, a standard Anderson-Darling test [24] with a standard level of confidence (commonly used in inferential statistics is  $\alpha = 0.05$  [25]) was done. The Anderson-Darling test hypothesizes that the sample follows a normal distribution and tries to reject this hypothesis. In our case, the test results in a  $P$ -value = 0.343 which is greater than  $\alpha = 0.05$ . Consequently, the null hypothesis cannot be rejected, and the “difference” sample is inferred to be normally distributed. Additionally, Figure 4 illustrates the Q-Q plot of the “difference” random variable. It plots the variable against the normal distribution and shows the measures falling randomly around the  $y=x$  line meaning that the sample follows a normal distribution.



**Fig. 4.** Q-Q plot of the “difference” sample confirming a normal distribution.

With the normality assumption checked, the paired  $t$ -test treats the hypothesis that the difference population mean is zero versus the hypothesis that it is less than zero.

Let us consider the standard level of confidence  $\alpha = 0.05$ . Applying a paired  $t$ -test to the values presented in Table 2 results in a  $P$ -value = 0.025. As the obtained  $P$ -value is below the 0.05 level of confidence, it is safe to reject the null hypothesis and conclude that the population mean of the “after” sample is less than the population mean of the “before” sample. Thus, it is statistically significant to say that the feedback method helped decrease the individuals’ proportional printing after it was applied.

#### 4.2 Team Level Printing Performance

Improving the teams printing performance is not the ultimate goal of the team-based feedback method. However, if the feedback is effective at persuading individuals within those teams, it is a natural consequence. In fact, it is possible to achieve statistically significant improvements at the individual level while failing at the team level if there are outliers who increase printing in a way that affects the sum of the overall team performance, but not the statistical significance of a large number of members who decrease their printing. Figure 5 illustrates the before and after team average proportional printing, measured as the average of sums of each team members proportional printing. All teams except unit 2 were able to reduce overall team printing.

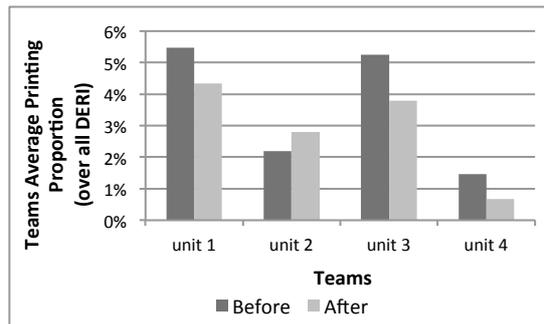


Fig. 5. Teams printing performance before and after applying the feedback method.

## 5 Discussion

In order to analyse the results of our experiment, we base the discussion on previous work by Medland [2]. Medland conducted interviews with key stakeholders to examine the attitudes and feedback preferences for printing consumption data. His study revealed three themes which we re-examine in light of our own study:

**Theme 1:** any printing conducted by staff was viewed as necessary, excepting accidents.

**Theme 2:** staff viewed different metrics as relevant or alternatively, as unnecessary for feedback on printing behaviour.

**Theme 3:** staff viewed co-workers championing reduced paper use as a helpful reminder to be conscious of how much they were printing.

### **5.1 Theme 1: All Printing is Necessary**

As presented in Section 4.1, five participants – about 31% of the participants – showed a slight increase in their proportional printing and thus did not respond to the feedback method. This observation suggests that an important incentive to persuade people to reduce their printing was not addressed by the team-based feedback method. This finding presents an interesting avenue for future qualitative research.

While the feedback method covers well themes 2 and 3 as discussed in Sections 5.2 and 5.3, it is likely that the driving force behind the non-responsive people not to reduce their printing is due to theme 1, i.e. their view that all their printing is rather necessary and cannot be avoided. Thus, this experiment raises attention to theme 1 found by Medland [2] and suggests that any feedback method needs to address fully or partially this theme to get better results, e.g. by changing business processes.

### **5.2 Theme 2: Flavoured Feedback**

Theme 2 suggests that different people have different views of what types of feedback are valuable or useful to them, such as traditional or eco-metric. Emails sent by our feedback software in this experiment applied these feedback methods in tandem. The empirical study showed a statistically significant proof that the feedback method helped decrease the printed-paper consumption in combination. Thus, stating the same information in different ways that address different models of individual perception is in fact a good feature of feedback methods confirming ideas presented in [2].

### **5.3 Theme 3: Comparison and Competition**

Emails sent by the feedback software included two types of comparisons: temporal and social. Temporal comparison contrasts team printing performance in a week to performance the week prior. Social comparison compares printing performance on a team-to-team basis. This study evaluated both types on a team-level rather than on an individual level. Results showed that the feedback method applied is sound and useful, as it has been able to form an incentive for individuals to lower unnecessary printing. That is consistent with theme 3 presented previously in [2].

Nevertheless, our experiment showed that the overall printing performance of some teams may not change even when the majority of team members are responsive. We posit that this is due to the fact that outliers may exist in a team with the feedback method unable to motivate them to reduce their usage. This raises interest in hybrid individual and team-based feedback models where predefined outliers can be targeted with personal feedback emails and other people with team-based feedback emails.

## **6 Conclusions and Future Work**

This paper reported an empirical study conducted in the Digital Enterprise Research Institute (DERI) over a year from October 2010 to November 2011. This study exam-

ined the hypothesis that a team-based feedback method can reduce individual consumption of a resource such as sheets of paper. Empirical results confirmed the hypothesis and showed an overall average reduction in paper usage of about 28% among the participants in DERI.

Of continuing interest to the researchers is the understandable function of a follow-up qualitative study, investigating participant experience, change of printing habits, and team dynamics. Qualitative methods would service a review of our already published findings, and provide rich in-depth accounts from individuals and teams, helping to strengthen and extend our findings in numerous ways. Discovering whether elements such as competition or communities of practise emerge is a research avenue of real value.

Future quantitative work would consider testing out the hypothesis with different types of resources such as electricity or non-renewable energy. Now that we have a significant result we would also seek to introduce further experimental conditions to strengthen our conclusions, such as providing another team with only verbal announcements “please print less”, or irregular and less granular feedback. A possible direction also is to leverage different forms and definitions of teams that go beyond top-down teams defined by organisational charts. An example can be bottom-up teams formed by participants in a work place dedicated for improving resource consumption. Another example is virtual online communities such as those formed on social networks.

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