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Are managerial pressure, technological control and intrinsic motivation effective in improving data quality?

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Can data collectors be "pushed" into collecting high quality data or would being "pulled" be more effective? This paper finds that managers should be careful of the degree to which "push" factors, such as managerial pressure and technological input control, are relied upon. While they may be helpful for motivating those data collectors who are not intrinsically motivated, they are either not helpful or may discourage those data collectors who are intrinsically motivated. Instead, self-concordance may act as a longer-term, more stable approach to increasing the motivation of data collectors and thus increasing the quality of data that enter reliability systems. This study uses a sequential mixed-method approach involving interviews with 20 data collectors and a quantitative survey of 109 data collectors in a water utility. It examines the interactive effect of managerial pressure, technological input control and self-concordance on data collection performance.

The need to improve the quality of manually-acquired data on assets is well-known in the reliability literature [1-4]. Manually-acquired data includes data gathered as a result of inspections, as a part of repair work, and during asset operation by personnel whose main role is to operate or maintain assets. These manually collected data are used, in conjunction with sensor data, to develop a picture of asset health and performance which informs decisions about asset renewals, repairs and replacements [5]. Recent integrations and critiques of the data quality literature [6, 7] showed that although many proposed solutions to poor quality data have involved cleaning the data once they have been collected [8] many are also aimed at influencing the input of the data – this occurs through either changing external factors that influence the data collector such as managerial and technology structures [e.g., 4, 5], or changing the motivation of the data collector [e.g., 6, 9, 10]. As yet though, little empirical research has rigorously examined the effects of the factors affecting the input of the data. Given the importance of high quality data in reliability systems, and the cost of cleaning the data after their collection, this neglect is surprising. This research therefore empirically tests the effect of the most common three factors (the manager, the technology used in inputting the data, and the intrinsic motivation of the data collector), as well as examining the effect of the interplay between them on the quality of manual data collection.

Although there has been considerable increase in the use of sensors and the volume of data collected by them, using operators and maintenance staff (data collectors) to collect data on assets is still a common practice. Manual data

collection leverages the experience of the data collector. It often requires them to provide an assessment of the asset's condition, identify a failure mode, or make a prediction as to remaining asset life in addition to recording observations or actions taken. However, when data collectors record their observations consideration needs to be given to psychological factors to ensure that appropriate factors are in place to encourage data collection of appropriate quality [6].

Like many psychological systems, we propose that data collectors can be "pushed" into collecting high quality data or "pulled" into it. Some reliability research has theorised factors that "pull" the data collector and encourage that individual to put effort into collecting high quality data. For example, Lee and Strong [11] found that knowing-why was important for data quality; Murphy [9] theorises that attitudes, social support and control would lead to data collectors wanting to collect higher quality data; and Unsworth and colleagues [6] propose that the multitude of goals that the data collector is trying to juggle and the relationship between the data collection task and his or her longer-term goals would affect the degree to which the individual wants to collect data and be "pulled" towards doing so.

On the other hand, the majority of the reliability literature has considered "push" factors. For instance, a review by Koronios and colleagues [5] suggested three main groups of factors identified in the data quality literature: technology (e.g., data storage and cleansing), organization (e.g. input control, role of managers, organizational structure), and people (e.g. performance evaluation). In most of these cases, the factors used to influence data quality are "pushing" data collectors to collect high quality data – the data collectors are required to collect the data or there will be negative consequences.

Yet little rigorous research has examined the effect of these "push" and "pull" factors and, to our knowledge, no empirical research has looked at the interplay between them. Do "push" factors which require the data collector to collect data (or risk negative consequences) increase the likelihood of the data collector putting more effort into collecting high quality data? Do "pull" factors, or wanting to collect high quality data, increase that effort? Moreover, when "push" factors are present, does that affect the potency of the "pull"? We integrate research from organizational behavior and organizational psychology with data quality research to empirically examine these questions.

2. FACTORS AFFECTING MOTIVATION TO COLLECT HIGH QUALITY DATA

It is generally accepted that for volitional acts, motivation drives our behavior [12]. It is the impetus behind effort and is defined as "the psychological process that influences how personal effort and resources are allocated to actions pertaining to work, including the direction, intensity and persistence of these actions" [13]. However there are two general categories of motivation: extrinsic motivation arising out of a requirement to do the task (the "push"

factors), and intrinsic motivation arising out of an internal desire to do the task (the "pull" factors) [14-16]. In the workplace, extrinsic motivation generally comes from a perception that you "have" to do something because of your boss, or your colleagues, your equipment, your need for your pay, and so forth; while intrinsic motivation generally comes from a perception that you "want" to do something either because it is important to you or you find it enjoyable [17].

As noted above, much of the previous data quality literature has identified factors that create extrinsic motivation. A review of the literature [1] suggests that the role of the supervisor and the performance evaluations made by them are key factors in the quality of data collection, covering both the "people" and the "organization" categories; the constraints placed on the data collector by the technology are also apparent within the literature and make up their own category [see 1, 5]. On the other hand, less research has addressed factors leading to intrinsic motivation for collecting high quality data [with exceptions: 6, 9, 11]. Our research will examine the effect of these three factors: the manager, the technological input control, and the intrinsic motivation to collect high quality data (see Figure 1).

Figure 1 about here

2.1 The manager

The manager (or supervisor) of a data collector plays a key role in determining the performance of his or her staff. One of the most robust and well-tested models of leadership is full-range leadership [18, 19]. This theory suggests that transactional leadership behaviors (including punishing errors and rewarding performance) operates as a foundation on which transformational leadership behaviors (including inspirational communication, consideration of each individual employee's needs, charisma, and intellectual stimulation) build. Considerable research has shown that each of these components are significantly related to leadership effectiveness [20].

Male supervisors often use transactional leadership behaviors, and in particular punishing errors [21]. In these instances, the supervisor is actively monitoring the performance of the employee and takes action when an error occurs [22]. Whilst such behavior from managers is sometimes not as effective in inducing performance as transformational leadership behaviors, meta-analyses have shown that it is still significantly related to overall leadership effectiveness [20, 23, 24]. Moreover, its substantial presence in blue-collar industries [e.g., 25] creates a need to examine these transactional leadership behaviors.

When considering data quality, both Murphy and Lin and colleagues suggested that managers need to provide feedback to operators [9, 26] which might likely entail disciplinary action. Disciplinary action and pressure from managers and supervisors creates extrinsic motivation as the data collector believes that he or she "has to" collect high quality data otherwise he or she will be sanctioned [24]. In the absence of any other form of motivation, extrinsic motivation leads to increased

performance [17, 24]. Thus, we hypothesise that:

Hypothesis 1: Pressure and disciplinary action from managers or supervisors will be positively related to the collection of high quality data.

2.2 Technological input control

The development of computerised maintenance management systems (CMMS) through the 1990s led to the need to codify maintenance and operational data in order to store it in the database. Lists and drop down boxes with pre-determined fields were developed, the design of which is imperative for performance. User-centred design approaches [27, 28] which recognise that there are physical, operational, environmental and social systems involved have been developed to help with decisions around the look and feel of the interface and how data are entered into the system.

Good practice in developing the interface involves direct interactions between the software team and groups of data collector and user representatives [29]. In practice it often proves laborious to find the right users, gain access to them and maintain involvement through the design project [30]. Moreover, interpretations of the same events, objects or people may differ due to their different sets of codes [31]. This is often the case with collection of operational and maintenance data as the language used by one tribe, the data collectors, can be quite different to that used by others, in this case the data collection system developers [32]. Ineffective communication about these differences during interface design and the consequent design of input controls that do not reflect the language and event representations of the data collectors can inhibit data collection. The response to these types of challenges by the database community has often been to focus on data cleaning once data have been collected into a database, and comparatively little attention has been paid to data quality at collection time [33].

The recent rapid growth in use of mobile technology has encouraged organizations to create transfer through the use of pre-determined forms to mobile Personal Digital Assistants (PDAs). These are taken on site by the data collectors as it is presumed that data is more accurate when it is recorded close to the point of action [5]. However there is evidence that older workers and those with limited computer experience, due for example to a life time of trades work, may find specific proscribed methods of data entry problematic, particularly on PDAs [34].

However in well-designed systems, the opposite effects would be expected. Wording to describe assets, events, and actions will be in a language familiar to the data collectors and requisite data can be entered efficiently and easily by those with even limited computer experience. The data can be translated in the language of the data user and is made available in using accepted codes for data features such as functional location, failure modes and actions taken. In these systems, the data collector will perceive that the system supports their efforts as it is an integral part of the requirements of their role thus extrinsic motivation is

created. As described above, in the absence of intrinsic motivation, extrinsic motivation should result in higher levels of performance [17], therefore we hypothesise that:

Hypothesis 2: The degree of input control perceived by the data collector will be positively related to the collection of high quality data.

2.3 Intrinsic Motivation and Self concordance

So far, we have considered two forms of "push" factors that create extrinsic motivation: managerial pressure and technological input control. However, intrinsic motivation may also be present for operators such that they believe in the importance of collecting data and want to put effort into collecting high quality data. Indeed, in a review of the maintenance literature in the field of avionics, Munoz and colleagues [35] state "In reviewing the literature, there is often an attitude that the challenge of maintaining sophisticated avionics systems is to provide tools to the maintenance technicians that compensate for his or her limited education, training, experience, and capabilities... The reality of the situation has been, however, that it has been the motivation, energy, and resourcefulness of the maintainers that has kept the airplanes flying, despite significant limitations in the tools they have been provided to do the work. And by tools, we mean data, procedures, processes, supports, hardware, software, test equipment, and so on" (p. 1341; emphasis added). Thus, the desire to perform the behavior is central to reliability.

Yet, as noted earlier, only a small amount of research in reliability has considered intrinsic motivation. The earliest work was by Lee and Strong [11] who found that "knowing-why" the data was needed and what it was to be used for was related to collecting high quality data. Such knowledge helps the data collector to have positive attitudes towards collecting data. As noted by Murphy [9], in another examination of intrinsic motivation, attitudes of the data collector, alongside the norms of the group and the control of the individual, leads to greater intrinsic motivation and greater effort. Finally, building on both these pieces of work, Unsworth and colleagues [6] suggests that these positive attitudes and norms create goals for the data collector and sit alongside the other goals that the person might have (such as being a good crew member, maintaining employment, and so on). The degree to which data collection is perceived as being related to more of these higher-order goals (i.e., they can "know why" it is important to them) the more effort they will put into collecting high quality data.

We take the latter approach as the most comprehensive assessment of intrinsic motivation within data quality to date. In particular, we examine goal hierarchy through self-concordance [36, 37]. Self-concordance is defined as the degree to which a task expresses an individual's interests and values [38] and thus represents a particular aspect of his or her goal hierarchy [39]. The extent to which individuals consider work tasks to be self-concordant has a substantial

effect on the motivation and effort invested in that task [19, 38, 40]. Highly self-concordant tasks represent the person's authentic interests and values and as such are integrated with the self; the individual wants to achieve the task because it helps their own longer-term goals [39]. Moreover, because it is related to these longer-term goals, the motivation is expected to be relevant for long periods and receive sustained effort over time [40]. On the contrary, when the same assigned tasks are less self-concordant for an individual, then the individual experiences an external locus of control, and all the "volitional strength" for the achieving the task is likely to fade when obstacles are encountered [40, 41].

We hypothesise that collecting high quality data will have varying levels of self-concordance for different data collectors. For some, the collection of high quality data will express their value of being a good team member and/or a good employee and/or an expert in their area. They might believe that collecting high quality data helps them to learn, provide for their family, do the best job possible, stay safe and be respected by others. They will therefore have high levels of intrinsic motivation and want to collect high quality data. Others, however, are unlikely to see how collecting high quality data can help them to achieve those goals. For them, collecting data is simply a task that they have been given and does not relate to any higher-order goals or values that they have. Given the arguments above, we propose that when a data collector perceives that collecting high quality data is self-concordant he or she will collect more high quality data than when a person does not perceive the data collection to be self-concordant.

Hypothesis 3: Self-concordance will be positively related to the collection of high quality data.

Thus, we suggest that both extrinsic motivation (in the form of managerial pressure and input control) and intrinsic motivation (in the form of self-concordance) will affect the quality of the data collected. Unfortunately, however, it is not quite this simple. Research into self-determination theory shows that the effects of extrinsic controls and intrinsic motivation on performance are not additive [15, 16, 42]. In fact, when extrinsic factors (in this case managerial pressure and input controls) are present then they may reduce the effects of any intrinsic motivation that the person originally started with [16]. For example, a person who is rewarded for being creative produces less creative work than someone who is not rewarded [e.g., 42] and a child who is watched and rewarded for play no longer finds interest in the game [43]. This occurs because the person loses his or her sense of control over performing the task; their interest and confidence in performing the task then decreases as they do not feel that they "chose" to engage in the task autonomously [16, 44].

For example, if an employee believes that it is important to collect high quality data to achieve their values and goals then they are likely to choose to put effort into doing so. If they experience overt (or unnecessary) managerial pressure they will start to feel controlled by the input technology they are using and will soon start to feel as though they are collecting data because they have to;

their sense of autonomous choice is diminished. Thus, at best the employee moves from being intrinsically motivated to being extrinsically motivated and there is no additive effect of being both intrinsically and extrinsically motivated. At worst, however, the intrinsically-motivated employee may resent the controls being imposed on them and may actually reduce their performance. Hence we might expect that an employee with low levels of intrinsic motivation (i.e., self-concordance), will respond positively to managerial pressure and input control as noted in Hypotheses 1 and 2; however for an employee with high levels of intrinsic motivation (i.e., self-concordance) then the presence of external controls such as managerial pressure and input control will either have no effect or will actually decrease his or her data collection performance.

Hypothesis 4a: Managerial pressure will be positively related to data collection performance for data collectors with low self-concordance; this effect will be non-significant or negative for those data collectors with high self-concordance.

Hypothesis 4b: Input control will be positively related to data collection performance for data collectors with low self-concordance; this effect will be non-significant or negative for those data collectors with high self-concordance.

3. METHODOLOGY

A water utilities organization with a large asset portfolio of $13.9 bn was the focus of this study as it had concerns about the quality of the data that were being collected by their maintenance and operations staff. The corporate risk profile identified that data quality was a risk that held moderate to major consequences to the company and was likely to occur; moreover the financial implications of the problem of data quality were immense. Therefore, the accuracy of data collected by operators and maintainers was critical in ensuring that the investment was performing, and would continue to perform, as required.

The organisation had recently implemented new PDA mobile data units. The decision had been made for three reasons: 1) To improve the monitoring of job times; 2) to better allocate units; and 3) to improve data integrity. The PDA were fitted with GPS therefore operators could easily be assigned to jobs closer to their location limiting travel from one site to another. Further as they could be taken on site operators were able to log information faster whilst the details of the task were still fresh in mind. Lastly the design of the PDA interface and data collection profiles was to ensure that only quality data be collected.

Manual data collection was done via operators. The operators were tasked with the job of attending to maintenance, failure and service upgrade activities for water service related assets as instructed by the organization (for example, changing water meters and fixing burst mains). In addition to these core job tasks they were also required to complete work order forms that recorded the specifics of the tasks they performed such as the time that they began the activity, the fault or maintenance code, the materials used, the services disrupted and the time they

finished the job. Other data were also required from them in the event that additional faults were discovered, as well as job safety assessments which were supposed to be completed prior to attending to any task. These data were recorded using a PDA and fed back to strategic asset management via the PDA. The failure to collect data using the PDA disabled operators from receiving further work orders.

This study examined the data collectors themselves and used a sequential mixed-method approach. Mixed-method research attempts to draw commonalities between the often conflicting paradigms of qualitative and quantitative data in order to produce a rigorous and complete understanding of social phenomena (Cameron 2009). By using multiple methods we are able to gain increased knowledge through both induction and deduction and to confirm findings through triangulation. Thus, to begin, we conducted interviews with data collectors and analysed the data from those interviews. A quantitative survey was then undertaken to both triangulate and build on those findings. Details of both stages are described in the following sections.

3.1 Stage 1: Qualitative approach

3.1.1 Interview development

To inductively determine what external "push" factors operated in this workplace and how they affected data quality, interviews were carried out with water service operators in one of the organization's regional offices. Initially 15 interviews were organised however it was found that an acceptable level of theoretical saturation had not yet been reached and the findings were not definitive [45]. Thus additional interviews were conducted leading to a total of 20 interviews lasting between 30-70 minutes in duration and over 80 pages of transcribed dialogue. The interviewees were male (98% of the organization is male) and covered both new recruits and seasoned veterans, and all types of roles (team leaders, mechanical and electrical tradesmen, and planners).

A semi-structured interview schedule was used because it allowed for additional probing of information and the elaboration of accounts by interviewees that otherwise may have not been possible from structured interviews (Cavana et al 2001). Furthermore the semi-structured interview structure allowed for comparisons to be made between accounts due to common elements in the questions asked, as opposed to completely open interviews with no structure at all (Punch 1998). The interview questions were constructed using the critical incident technique (Flanagan 1954). In this instance, the critical incident technique took the form of: "Tell me about a time when you believe you or another operator collected and recorded all relevant data about an asset's failure? (When answering please refer to what the problem was, what was done to resolve the problem, what data was collected and what the end result was)".

The interviews were then analysed. The responses were interpreted line-by-line using thematic analysis to produce themes to represent possible factors that affected collection of data. Thematic

analysis is the process of categorising datum into patterns and themes to better explain and understand a social phenomenon (Boyatzis 1998). The themes used in this study were generated by the intensity and frequency of operator responses, which was noted during each interview, as well as the relation of responses to data quality. Whilst the themes that were generated in this study were created from the data, they were compared to existing constructs in the literature to ensure that they were theoretically valid [46].

3.2 Stage 2: Quantitative study

3.2.1 Sample & Procedure

The surveys were distributed to approximately 600 operators in six different geographical regions via the internal mail system. These operators represented all types of data collectors within the organization. The surveys were accompanied by a covering letter explaining the aims of the study and assured the confidentiality of the responses. Also attached was a separate document that allowed operators the chance to win a $50 gift voucher for participating in the study, which was to be returned separated from the survey itself. The chance to win a prize was chosen to act as an incentive to improve the response rate because of the generally low rates typical of mail based questionnaires [47]. One hundred and nine responses were returned (approx. 20% response rate). The response rate is common for this type of survey and for this population (an internal questionnaire the previous year regarding the use of the PDA for data collection had received only 35% response).

3.2.2 Measures

A pilot study was conducted prior to the distribution of the survey to ensure that it was easily understood and that it was not too long. The participants in the pilot study were individuals who worked closely with the operators. The pilot study indicated that some items needed to be re-worded and other items needed to be excluded due to the overall length of the survey. These recommendations were followed. Unless mentioned otherwise, the measures used a five point scale (from 1 "Not at all" to 5 "A great deal") to keep the items consistent. The following describes the final measures used.

Managerial pressure

In order to explore the effect of managerial pressure the survey used three items to measure contingent punishment behavior defined as "the degree to which a leader administers punitive events dependent upon poor performance" [48]. The items were: "My supervisor lets me know when I collect data poorly"; "My supervisor would discipline me if my data collection was below standard"; and "When my data is not correct, my supervisor points it out to me". The internal reliability of the scale was high (= .80).

Technological input control

The operators' belief that improvements in technology could affect their ability to ensure data quality was unique to this study, therefore to measure this construct a single item measure was developed by the researcher with the guidance of subject matter experts. This

item was "The PDA ensures that I collect accurate data".

Self-concordance

Self-concordance was measured through identifying the degree to which data quality was related to the operator's higher-order goals. The higher-order goals used in the surveys were based on the most common ones identified in the interviews and covered two levels (identities and long-term goals). The possible identities were: team leader, team-member/co-worker, maintenance contractor, [organization] employee, father/mother, husband/wife, member of volunteer organization, and expert in your skill area. The possible long-term goals were: have control over job tasks, learn as much as I can, provide for family, help my co-workers, improve my performance, attend to as many jobs as possible, do the best job possible, keep myself safe, be respected by supervisors, help customers, maintain employment, retire, and be respected by co-workers.

We followed the methods used by Sheldon and Kasser [49] and Adriasola and colleagues [39] to measure self-concordance. In this study individuals were asked to rate the personal importance of the identities and the long-term goals. Then in order to elicit the interrelationships between the identities, long-term goals and data collection tasks, the survey questions asked how helpful collecting accurate work data was to achieving each of the higher-level goals. To create an overall measure of self-concordance, we first multiplied the importance of each of the higher-order goals with the relevant helpfulness rating. For example, we multiplied the rating of importance of being a team member to the degree to which data collection was helpful in being a good team member. Thus, if collecting high quality data was very helpful in achieving a goal that wasn't important to the employee it was weighted less strongly than when it was helpful in a achieving a goal that was important. Each of these weighted helpfulness ratings were then summed to create an overall measure of self-concordance.

Data collection performance

Data collection was the dependent variable of the model; it refers to the self-reported performance of operators at collecting quality data. Four context-specific items were created to measure the quality of the collection of work order and job safety assessment data. It was based on the accuracy and completeness dimensions only [11, 50] because the timeliness and accessibility of the data is not within the control of the operator. The items were: "I collect accurate work order data"; "I collect all the required work data"; "I collect accurate mandatory data"; and "I collect additional data (e.g., comments)". The internal reliability was strong (= .83).

Controls

Discussions with people within the focal organization suggested that two other factors might be affecting the quality of data collection. The first of these was the length of time the person had worked for the organization; those who had worked there longer were presumed to be more willing to record accurate data. The second was the stability of the area in which the person worked; the more they worked in the same area the more

they were presumed to want to have accurate data to work with. Thus, we measured organizational tenure ("How long have you been working for [organization]") and stability of area ("To what extent do you perform services in a set area (district/zone) on the same assets (pipes/stations/meters)"). These were included as control variables in the regression equations to remove any potential noise due to these demographic variables.

4. RESULTS

4.1 Interview Results

Thirty-five percent of interviewees indicated that they were able to identify at least one time in the past year when they had inaccurately or incompletely recorded work order data. Interestingly a large proportion of all interviewees only made a superficial connection between data and their job, stating that without the work order data they would not be able to have their work order signed off, indicating only extrinsic motivation for completing the task. Most did not link the importance of data quality to issues beyond their immediate personal financial goals; only a small minority of operators indicated that ensuring data quality led to the meeting of customer service key performance indicators or because they genuinely wanted to excel in their work. In other words, there was a relatively low level of self-concordance in this interview sample.

When examining the effect of external controls on data quality, we did indeed find that supervisor pressure and technology emerged spontaneously. First, the interview data indicated that the operators who reported high levels of data quality feared the disciplinary action of their supervisors. However, it was not a simple relationship. Those who felt this way also had personal goals linked to security and safety. One interviewee put it this way, "I do my job well, if I am good by them (supervisors), they leave me alone, I'm good." In short, supervisor pressure was useful in increasing data quality for those operators who were focused on job security.

With regard to the input control system, most operators felt that it made ensuring data quality easier. One operator pointed out that "the new system still needs getting used to, but it is the future and I can see why we need to use it." However, some still felt the "system" was to blame for the inaccuracies in data collection; these participants were characterised by their cynicism towards the authority of the organization and the efficiency of the PDAs. These operators felt that the improvements in technology actually led to a reduction in their performance to ensure data quality. They felt that the system was restrictive and slow with one operator stating that "Scrolling through the PDA options takes longer than actually writing it down...sometimes some parts are not even in the drop down menu." Other members of this group stated that despite writing down accurate data the data storage system was corrupt and that corruption was what was making the end user data inaccurate. For example, one operator did not believe that his co-worker forgot to close off on a job but instead thought it was the system's fault that the job was reallocated to him.

4.1.1 Analysis of Interview Results

The interviews enabled us to capture information about data quality motivation and performance with minimal influence from the researchers. Using an inductive approach, we found that there were two external motivating factors to have a major role in affecting data quality: managerial pressure and input control. However, these factors were not operating consistently across all the operators. More specifically, managerial pressure was identified by operators who felt coerced by their supervisor but who felt the need to listen to managers and who exhibited a subordinate identity. A subordinate identity is identified by the individual's belief that the power of supervisors can affect their outcomes [51]. Individuals who embody strong orientations to this identity were thus more likely to be motivated to collect high quality data when they felt pressure from their supervisor. On the other hand, input control was identified by operators who believed that improvements in technology either improved or hindered their ability to ensure data quality. Thus, the interviews suggest that moderating effects are occurring; that the motivating factors are relevant for some people but not others. The survey study was designed to test whether these factors do have a significant effect on data quality on a wider population, and whether self-concordance also acts to buffer their effects.

4.2 Survey Results

The means, standard deviations and correlations of the variables are provided in Table 1. When looking at the self-concordance and goal hierarchy data, it was found that over 80% of operators felt that "collecting accurate data" was helpful for fulfilling their personal projects of "helping co-workers," "improving performance," "doing the work as best I can," "keeping myself safe," and "maintaining employment" (ranking the helpfulness of collecting accurate data to the fulfilment of these personal projects either 4 or 5 out of five scales). However, only three of these five personal projects were seen to be important to operators. Furthermore "collecting accurate data" was not seen to be helpful in fulfilling any of the operators' identities. Thus, overall the self-concordance levels (that is, the connections weighted by their importance) were only moderate.

To test the hypotheses, we conducted two hierarchical regression analyses for the two different external factors under study. The steps detailed in the columns of Table 2 show the different stages of the two regression analyses. All of the steps (and variables within the steps) are trying to explain the variance in data collection effort. We controlled for organizational tenure and the stability of the area in which the operator worked in the first step of the equation, thus all variance in data collection effort associated with tenure and work stability was removed and the remaining variance left to be explained could not be attributed to these demographic variables. In the second step, we included self-concordance and the external factor [both centered, as per 52], meaning again that the remaining variance left to be explained could not be attributed to tenure, work stability,

self-concordance and managerial pressure/input control. In the final step of the equation we included the interaction term comprised of a multiplication between the centered self-concordance and the centered external factor [52, 53]. Having these separate steps means that we get a more accurate picture of the individual contributions of the variables. We did not remove non-significant variables from the equations as they are still theoretically relevant and their removal might produce spurious results.

Hypothesis 1 suggested that managerial pressure would be significantly and positively related to collecting high quality data. As can be seen in Table 1, managerial pressure had a significant bivariate correlation with data collection ($r = .19$, $p<.05$). However, after controlling for tenure, work stability and self-concordance, managerial pressure did not have a significant main effect in the regression analysis ($\beta = .14$, n.s.), indicating that, overall, increasing external control through supervision did not increase the quality of data collection. Thus, hypothesis 1 was not supported.

Hypothesis 2 was concerned with the effect of technological input control. Again, Table 1 shows a significant bivariate correlation ($r = .31$, $p<.01$). Moreover, the regression analysis demonstrated that input control through PDA technology was significantly and positively related to collecting high quality data ($\beta = .25$, $p<.05$) even after controlling for confounding and other motivational factors. Hypothesis 2 was therefore supported.

Hypothesis 3 suggested that self-concordance would have a positive relationship with data collection performance as it indicates intrinsic motivation to collect high quality data. This hypothesis was supported in the bivariate correlation ($r = .30$, $p<.01$) and both regressions ($\beta = .27$, $p<.01$; $\beta = .23$, $p<.01$; respectively).

Finally, we tested our moderating hypotheses. The first regression tested the extent to which the effect of managerial pressure was altered depending upon the level of self-concordance. We predicted that while the effect for pressure would be positive for those with low self-concordance, it would be neutral or negative for those with high self-concordance and we found support for this hypothesis ($\beta = -.28$, $p<.01$). The interaction is plotted in Figure 2 (the lines in the graph represent the regression equation at one standard deviation below and one standard deviation above the mean of self-concordance) and is in line with the hypothesis. Further investigation of the simple slopes found that for those with low self-concordance there was a significant positive effect for managerial pressure ($t = 3.67$, $p<.01$), but for those with high self-concordance there was a significant negative effect for managerial pressure ($t = 1.97$, $p<.05$). In other words, when the operator was not intrinsically motivated then managerial pressure provided some motivation to collect high quality data; but for those already intrinsically motivated then managerial pressure significantly reduced high quality data collection.

Figure 2 about here

The second regression analysis was the same as the first, but instead of self-concordance moderating the effect of managerial pressure, we examined the effect on input control. Hypothesis 4b suggested that those with low self-concordance would maintain the positive relationship found earlier, while those with high self-concordance would exhibit a less positive relationship. Our results found support for this hypothesis; the interaction term was significant (= -.20, p<.05) and the interaction is plotted in Figure 3 where again the lines represent the regression equation at one standard deviation below and one standard deviation above the mean of self-concordance. Similar to managerial pressure, and in support of our hypotheses, input control was positively related to data collection when the operator had low self-concordance (t = 3.34, p<.01). For those with high levels of self-concordance, however, input control through the use of PDA technology had no significant effect on data collection (t = .53, n.s.). Thus, input control appears to work only for those with low levels of self-concordance and there is no additive effect for those who are already intrinsically motivated.

Figure 3 about here

5. SUMMARY OF RESULTS

In summary, we found that managerial pressure did not have an overall effect on the workplace as a whole. Instead, pressure from the supervisors to collect high quality data increased the performance of some operators, but decreased the performance of other operators. The interviews showed that pressure from the supervisors was only important for those who had a submissive identity towards their supervisor. Furthermore, the quantitative surveys showed that managerial pressure only had an effect for those who had low levels of self-concordance: it had the opposite effect for those who had high levels of self-concordance and were intrinsically motivated. The use of managerial pressure was demotivating for those data collectors and reduced their collection of high quality data. Monitoring and sanctions from supervisors and managers in the aim of increasing data quality, therefore, may be a double-edged sword.

Similarly, although in a less striking fashion, controlling the input process through technological constraints was effective for those who had low levels of self-concordance but had no effect on those who had high levels of self-concordance. In other words, there was no benefit in spending money on the increased technological control for those people who were already intrinsically motivated. Moreover, the interviews showed that there was still some cynicism around and resistance to the new technology. These findings converge with other evidence which shows that while new technology aided data collectors by providing a list of possible options, these lists also presented challenges [54-56]. For example, it is common to provide lists for a) what part failed, b) what caused the failure, and c) what work was performed. If these lists are too generic, personnel get frustrated that the item selected does not adequately represent their view [54, 55]. Conversely if the list is detailed and long, they get frustrated trying to differentiate between items and in scrolling down to find the “right” item

[56]. In other cases the poor selection of items on the lists means that none of the items in the list reflect the way in which the item fails or the work done. Thus, the use of technology to control the input from data collectors appears to also be a fraught issue.

6. DISCUSSION

The manual collection of asset data is a common, and in many cases, necessary procedure to develop information sets for asset decision making. Unfortunately, as much research attests, the motivation for collecting such data is often low and these data remain unusable [see 6, 35] or require significant cleansing after-collection to make it usable [8]. Our study aimed to investigate some of the psychological factors, namely extrinsic and intrinsic motivation, that affect the collection of high quality data. We suggested that intrinsic motivation (i.e., motivation derived from wanting to do the task) stemming from the self-concordance of the data collection task would be important as both a significant factor in its own right and as a neutraliser of the relationship between the external controls (managerial pressure and input control) and data quality. We found that such effects did occur and that simply increasing the technological input control or the monitoring and sanctions by supervisors would not lead to an equal increase in effort for those with high self-concordance. Indeed for those people, increasing managerial pressure had the opposite effect and actually reduced their performance.

6.1 Implications

From a theoretical perspective we can explain these findings through a perception of control. When people perceive their actions to be controlled by others and not chosen by themselves, their overall motivation is reduced [38, 41, 57]. It is likely that the operators who were intrinsically motivated through self-concordance perceived the PDAs to be controlling their actions somewhat and the pressure from the supervisors to be controlling their actions a great deal. In other words, when dealing with the new technology they probably still felt as though they collected high quality data, not just because of the PDA, but because they thought it was important; but when dealing with a supervisor who might punish them, they probably felt as though they were now collecting data only because they had to avoid punishment. On the other hand, when self-concordance was high and there were no external factors, the employees felt that they were collecting data because they themselves were choosing to do so. Such differences in perceptions of control have been shown in a great deal of psychological research to have significant effects on motivation and performance [15].

These results have very important practical implications: External controls should be used with caution. While input control via technology did not have negative effects on motivation for data collectors who viewed the task as self-concordant, it did not have a positive effect either. Therefore a cost-benefit analysis will be necessary. If most employees are not intrinsically motivated (i.e., have low self-concordance) then the

money invested in improving the technology to control the input process should result in overall increases in the quality of data collected. On the other hand, if most employees are intrinsically motivated then the benefits will not arise and it is unlikely to be worth the money invested.

More important is the use of manager and supervisor pressure. In many industries, the traditional approach is to use monitoring and managerial sanctions to change behavior. As we have shown, however, this can have significant negative effects for those who might be intrinsically motivated. Rather than an habitual reaction towards sanctioning employees, greater training of supervisors to help them differentiate those who are motivated by self-concordance and those who are motivated by external controls should help in this regard.

This research suggests that alternatives need to be provided to the straightforward use of external, "push" factors. We are not suggesting that managers and supervisors do not monitor their employees or use transactional leadership, and we are certainly not suggesting that PDAs not be used for input control. However, we propose that they not be the first port of call, nor relied upon completely. An alternative approach might be one which uses two stages to change the behavior of the data collector. To begin, the organization could aim to increase the self-concordance of the employees. This should mean that a majority of the employees are collecting high quality data because they are intrinsically motivated to do so. While effort based solely on "push" factors require that those factors be present or the behavior will be extinguished [58], because highly self-concordant goals represent the person's authentic interests and values they are integrated with their identity. As noted earlier, this means that the self-concordant goals are expected to be relevant for longer periods of time, increasing the time over which they will receive sustained effort. In the second stage, those who were still not collecting high quality data and whose self-concordance was not increased could be monitored more closely and reinforced accordingly by managers. In using such a staged approach, organizations would be able to ensure that those who were intrinsically motivated were able to remain motivated and collect high quality data; but those who still had low levels of self-concordance could be targeted to ensure that they too collected data.

So how can you increase the self-concordance of this task with the data collector's goals? Following Unsworth and colleagues [6] this could be achieved through interventions aimed at increasing operators' awareness of their own higher level goals and the role that data quality has in contributing towards those goals. Individuals do not often make conscious decisions or consider how goals at different levels could be helpful in achieving each other; thus interventions based around increasing self-awareness of higher-order goals have the potential to help build self-concordance for different tasks of the job. Furthermore, research has shown that transformational leadership behaviors are related to increased self-concordance in followers [19, 37]; there

is therefore the potential to re-direct the resources invested in supervisors such that they improve their transformational leadership skills.

7. CONCLUSIONS

This research is one of the few studies to empirically examine the motivation of data collectors [others include 11, 59]. We used a sequential, mixed-method approach which enabled us to use both inductive and deductive reasoning in determining the most salient factors affecting the collection of data. At the same time, however, the study does have its limitations. First, we used self-report data for data quality and relied upon the honesty of the participants in their responses. Nevertheless we emphasised our independence as researchers and the anonymity of the methods and the participants therefore had no reason not to tell the truth; moreover, the fact that we found significant relationships in the data supports our belief that the data are valid. Second, this was the first time that technology as input control has been studied empirically. Our study included two dimensions that might be affecting motivation through input control: a) requiring data collectors to choose items from lists and b) use of mobile technology itself. Future research should undertake to differentiate these, and other possible, dimensions of technological input control to further understand its effects.

In summary, our research took a rigorous empirical approach to understanding the effects of "push" and "pull" motivational factors on quality of manual data collection. Our take-home message is to be careful of the degree to which "push" factors, such as managerial pressure and technological input control, are relied upon. While they may be helpful for motivating those data collectors who are not intrinsically motivated, they are either not helpful or are detrimental to those data collectors who are intrinsically motivated. Instead, using self-concordance as a way of motivating data collectors to collect high quality data may act as a longer-term, more stable approach to increasing the quality of data that enters reliability systems.

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Table 1. Means, Standard Deviations, and Correlations between Study Variables.

	Mean (sd)	Area stability	Managerial pressure	Input control	Self-concordance	Data collection
Tenure	3.57 (1.93)	.11	-.01	.02	.16	.03
Area stability	3.86 (1.48)		.06	-.06	-.05	-.01
Managerial pressure	3.46 (1.05)			.31**	.20*	.19*
Technological input control	3.39 (1.36)				.32**	.31**
Self-concordance	355.37 (101.62)					.30**
Data collection effort	4.28 (.74)					

*p<.05; **p<.01

Table 2. Results from Hierarchical Regression Analyses on Data Collection Effort.

	Managerial Pressure			Input Control		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Tenure	.04	.01	-.03	.07	.04	.01
Work stability	-.02	-.01	.01	-.04	-.01	.01
Self-concordance		.27**	.23*		.23*	.17
Managerial pressure		.14	.09		-	-
Input control		-	-		.25*	.25*
Interaction term			-.28**			-
Interaction term			-			-.20*
R^2, significance	.04, F(2,100)=.09, n.s.	.33, F(4,98)=3.1, p<.05	.43, F(5,97)=4.3, p<.001	.01, F(2,94)=.29, n.s.	.40, F(4,92)=4.31, p<.001	.44, F(5,91)=4.30, p<.001

Figure 1. An Illustration of the Hypotheses

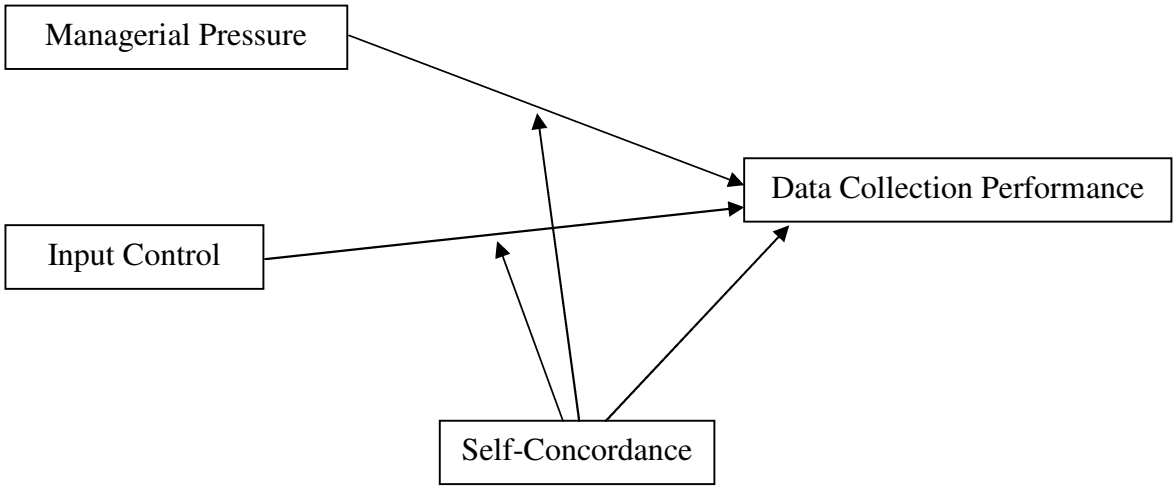

Figure 2. The Neutralising Effect of Self-Concordance on the Relationship between Managerial Pressure and Data Collection.

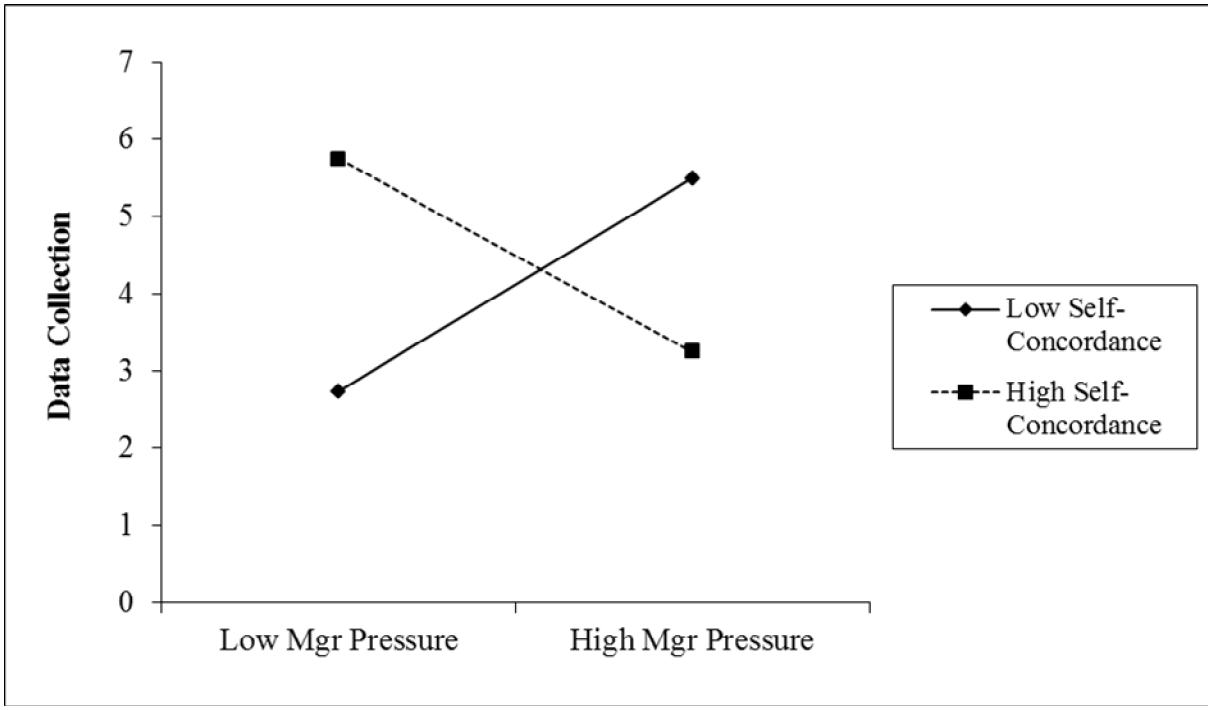

Figure 3. The Neutralising Effect of Self-Concordance on the Relationship between Input Control and Data Collection.