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RESEARCH ARTICLE

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Workers' Acceptance of Digital Procedures: An Application of the Technology Acceptance Model

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OCCUPATIONAL APPLICATIONS

There are increasing numbers of organizations that are implementing digital procedures (e.g., standard operating procedures). These efforts are often assumed to be a positive development but can be quite costly—both in terms of money and training for a digital rollout. As a result, organizations and practitioners may find themselves at risk for failure when implementing digital procedures. The results of the current study suggest that if workers perceive digital procedures as useful and easy to use, this perception translates into positive attitudes, which subsequently result in fewer deviations. Since acceptance is relatively easy to assess, practitioners can benefit from using these assessments prior to a digital transition/roll-out to both compare competing hardware and software applications, and to initiate and continuously monitor the development of digital procedures. We consider this approach as advantageous to having management develop a system and fully deploying digital procedures without any consideration of worker acceptance.

TECHNICAL ABSTRACT

Background: There is increasing prevalence of digital procedures being introduced in the process safety industries. Presumably, this increase is due to a desire to take advantage of the technology afforded to workers that otherwise is not inherent to traditional paper-based procedures. A critical question that has not been addressed, though, is to what extent do workers accept this new technology in a new digital procedure rollout? Furthermore, does acceptance lead to procedure-related behavior, such as procedure deviations?

Purpose: We used the technology acceptance model (TAM), which includes two dimensions of technology acceptance—perceived usefulness (PU) and perceived ease of use (PEU)—as the focal antecedent constructs. We hypothesized that these constructs would predict more proximal attitudes toward procedures, which in turn predict procedure deviations.

Method: We used path analyses to test six study hypotheses developed from the TAM. Data were collected from 16 workers at a large, international chemical corporation that worked in logistics. Specific measures obtained were from multi-item, Likert-scale measures of the TAM-PU and PEU dimensions, utility and compliance attitudes toward procedures, and procedure deviation frequency.

Results: Four of the six study hypotheses were supported. TAM-PU and TAM-PEU both significantly predicted (positively) utility attitudes toward procedures (71% variance explained), whereas only TAM-PU significantly predicted (positively) compliance attitudes toward procedures (63% variance explained). In turn, only compliance attitudes significantly predicted (negatively) how frequently workers deviated from procedures (27% variance explained).

Conclusions: These results suggest that workers were generally accepting of the digital procedures and that worker perceptions of perceived usefulness perceptions likely have an indirect effect on procedure deviation frequency. We see this study as a novel contribution to the process safety and procedures research domain. Limitations and future research directions will be discussed.

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1. Introduction

In high-risk process safety industries such as oil & gas, chemical, and nuclear, written procedures have become an important mitigation method for preventing safety incidents (Amyotte et al., 2007; Bullemer & Laberge, 2010). However, procedures are not always effective, as procedure misuse and deviations continue to be cited as contributing factors to devastating incidents such as the Macondo blowout (CSB, 2016) and ExxonMobil Torrance refinery incident (Chemical Safety and Hazard Investigation Board, 2017). To address deficiencies in procedures and procedural systems (e.g., procedures not updated or correct), some organizations are transitioning from paper procedures to various types of digital procedures—similar to the electronic checklists adopted by the aviation and medical fields (e.g., Carim et al., 2016; Kulp et al., 2017). However, since procedures in the process safety industries differ in terms of structure, purpose, and content from electronic checklists, there is a gap in procedures research regarding the effectiveness of digital procedure adoption. A critical issue when companies adopt new technology is the presumption that this switch will improve worker performance *and* the implementation will be cost-effective. Yet, if workers are reluctant to (or altogether do not) use a new technology, the organization will have likely wasted resources including the development of the technology and its implementation (e.g., training workers). Accordingly, the broad purpose of our study was to examine the relationship between substantive procedure-related variables in the context of digital procedure adoption.

In process safety, a digital procedure often refers to the dynamic and interactive presentation of the steps of a task (e.g., signing off steps, initiating the procedure change process, note-taking, time stamps, etc.) and the hardware and software needed to accomplish these steps. One key component in the process of implementing new technology—digital procedures—is that workers are accepting of this technology. Numerous studies have demonstrated that acceptance of technology is a critical variable to predict subsequent behavior (e.g., Davis, 1986, 1989; Davis et al., 1989; Dou et al., 2017; King & He, 2006; Mathieson, 1991; Park, 2009), however little is known about worker acceptance of the conversion of paper procedures to digital procedures. Given the strong relation between acceptance and use in previous domains, it is important to explore: (1) worker acceptance of digital procedures; and (2) whether acceptance is associated with behavior. Specifically, for the current study, we are not simply interested in whether workers accept digital procedures, but to also determine whether technology acceptance of digital procedures leads to desirable outcomes such as better attitudes and fewer procedure deviations.

1.1. Background and Study Variables

Technology Acceptance: Perceived Usefulness and Perceived Ease of Use

In the original Technology Acceptance Model (TAM; Davis, (1986, 1989), it is stipulated that technology acceptance is driven by two distinct factors. The first, *perceived usefulness* (PU), is the extent to which individuals see a connection between using a new technology and that use translating to increases effectiveness, efficiency, and productivity. The second factor, *perceived ease of use* (PEU), is the individual's perception of how much effort and time would need to be allocated to develop the skills to use the new technology. In the original TAM, these variables predict attitudes toward the technology—better perceptions lead to more favorable attitudes. In more recent models, the examination of the link between PEU/PU and attitudes has decreased, and the focus has been shifted to PEU/PU and behavioral intention. Indeed, the link between intention to use and actual behavior is the most robust finding in TAM research (King & He, 2006) and is thus not examined in the current study. It is the relative inconsistency of attitudinal inclusion in studies and subsequent inconsistency in empirical results between acceptance and attitudes that is a limitation in this domain (cf. Alper et al., 2007; Park, 2009).

Procedure-Related Attitudes and Deviations

Previous studies and reviews regarding predictors of procedure violations have identified attitude toward compliance as one of the individual-level variables that frequently predicted procedure violations (Alper & Karsh, 2009; Hendricks & Peres, 2021). Accordingly, Hendricks and Peres (2021) developed two attitudinal measures—*attitude toward procedure compliance* (compliance attitude) and *attitude toward procedure utility* (utility attitude). Compliance attitude is a worker's judgment (favorable or unfavorable) toward the extent to which workers should strictly comply with procedures. Utility attitude refers to a worker's judgment (favorable or unfavorable) toward procedures and is rooted in the artifact's (here, the procedure) utility. Utility attitude was developed by taking a systems approach and viewing procedures as a tool and resource for action. The conceptual underpinning for utility attitude is that workers are unlikely to use a tool they view as not being useful. Finally, procedure *deviation* is considered a procedure-related behavior; it is the frequency of instances where workers either do not perform steps, do steps out of order, or any other deviation from written procedures. Deviation is an important behavioral measure for procedural systems research as it has been associated with incidents and near-misses both in the formal investigations of incidents and in empirical research (Hendricks & Peres, 2021).

1.2. Integration – Theoretical and Empirical Bases

Previous reviews have discussed evidence for linkages between compliance attitudes and deviations (see Alper & Karsh, 2009; Hale & Borys, 2013a). However, there is not as much evidence for relationships between workers' attitudes toward procedure utility and their deviation from those procedures. When testing models that included both attitudes toward compliance and utility as predictors and deviations as the criterion, Hendricks and Peres (2021) found that compliance and utility attitudes uniquely predict deviations—favorable compliance and utility attitudes were associated with fewer deviations.

The criterion of interest in the current study is deviations and the framework used is an adaptation of the original TAM. We are most interested in examining whether the acceptance constructs of PEU and PU for digital procedures predict the more *proximal attitudinal predictors* of deviations (i.e., utility and compliance attitudes). Specifically, we examined whether the acceptance of the newly implemented digital procedures (indicated by the PEU and PU dimensions in the TAM) predict attitudes toward procedures (utility and compliance attitudes). Furthermore, we sought to replicate the attitude → deviation relationship found in previous studies using the attitudinal variables regarding utility and compliance (Davis, 1986; Davis et al., 1989; Hendricks & Peres, 2021).

Although other studies have excluded attitudes in the TAM (see King & He, 2006), we argue that it is theoretically deficient to do so, especially for the context of the current study. Indeed, we elected to focus on attitudes: 1) because they are an integral part of the original TAM and both the theory of reasoned action and planned behavior (Ajzen, 1991; Fishbein & Ajzen, 1975); and 2) within the context of procedure-related behavior, there is evidence that procedure-related attitudes are directly related to the behavior of deviation (Hendricks & Peres, 2021).

1.3. Current Study Model and Hypotheses

As previously stated, we are seeking validity evidence for the TAM by leveraging the uniqueness of workers having recently experienced a digital procedure rollout (the technology to be accepted or not) in a high-risk process safety industry. We acknowledge that our adoption of the original TAM and integration of key constructs from Hendricks and Peres (2021), essentially creating an adapted model, is not a comprehensive model or theory of procedure-related behavior. That would be beyond the scope of our initial research questions, hypotheses derived from the modified TAM, and the data collected. We recognize that not all deviations from procedures are "bad" and indeed can be adaptive (e.g., Ashraf et al., 2021, 2022; Dekker, 2003; Hale & Borys, 2013a; Hollnagel, 2018). Nevertheless, if we define deviations (or less ominously, variations) as the inequivalence between work as imagined and work as done (including successful deviations), then fewer deviations is still a goal of the procedural system. Instead of demanding rigid compliance with static paper procedures, we see digital procedures as a conduit through which entire procedure systems support workers and their need to be adaptive in various contexts.[1]

In the current study, we propose the following model (see Figure 1). This model includes technology acceptance of digital procedures (i.e., perceived ease of use and perceived usefulness) as distal predictors of the more proximal predictors of deviations, which are attitudes (i.e., compliance and utility) toward procedures.

There is evidence from previous studies (Davis et al., 1989; Park, 2009) that PEU and PU predict attitudes toward system use. Conceptually, it makes sense that if individuals are accepting of digital procedures on the basis of perceived usefulness and perceived ease of use that they will, in turn, have more favorable attitudes toward procedures in general, because individuals are rewarded (or avoid punishment) for more effective, productive, and safe work. Accordingly, we hypothesized the following:

> *Hypothesis* 1: Perceived usefulness of digital procedures will predict utility attitudes toward procedures such that the more one perceives the procedure as useful, the more likely they will have favorable attitudes toward the utility of procedures.

> *Hypothesis* 2: Perceived usefulness of digital procedures will predict compliance attitudes toward procedures such that the more one perceives the procedure as useful, the more likely they will have favorable attitudes toward procedure compliance.

Similarly, the more workers accept digital procedures based on perceived ease of use, the less likely this translates into anticipating having to allocate as much effort and time to using digital procedures. This reduction in allocated effort and time will likely lead to more favorable attitudes toward procedures in general. Accordingly, we hypothesized the following:

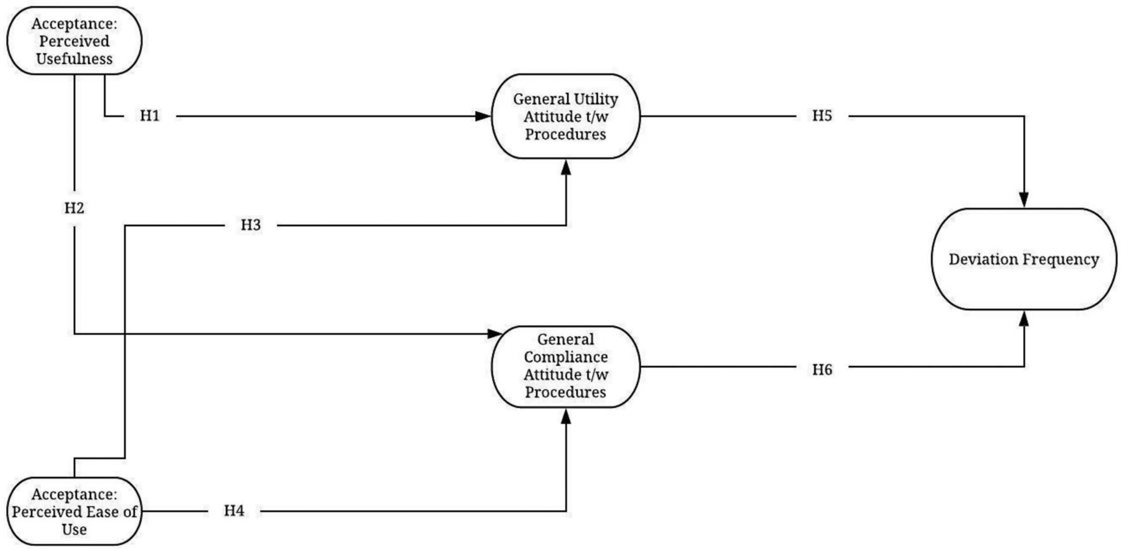

Figure 1. Hypothesized model of technology acceptance, attitudes toward procedures, and deviations. H1-6 indicates the study hypotheses, which are provided in the text.

> *Hypothesis* 3: Perceived ease of use of digital procedures will positively predict utility attitudes, (i.e., the more workers perceive procedures as easy to use, the more favorable their attitudes toward procedure utility will be).

> *Hypothesis* 4: Perceived ease of use of digital procedures will positively predict compliance attitudes (i.e., the more workers perceive procedures as easy to use, the more likely they will have favorable attitudes toward compliance).

We take a systems approach to the acceptance of technology, but also to the procedure system as a whole. We sought to replicate the Hendricks and Peres (2021) findings to fully integrate the TAM and the findings of more proximal attitudinal predictors of deviations. Accordingly, we hypothesized the following:

> *Hypothesis* 5: Attitudes toward procedure utility will predict procedure deviations, such that with more favorable attitudes, fewer deviations will be reported.

> *Hypothesis* 6: Attitudes toward procedure compliance will predict procedure deviations, such that with more favorable attitudes, fewer deviations will be reported.

2. Method

2.1. Participants

We recruited and enrolled 16 workers employed at a large, international chemical corporation to participate in this study. The participants worked at one of two different sites (Site A, $n = 9$; Site B, $n = 7$) and worked in logistics (e.g., loading chemical products on rail cars). More specifically, 10 individuals self-reported that they loaded tank trucks and railcars, five reported packaging, and one reported "other". The age range was 21–56 years ($M = 34.06$, $SD = 9.26$) and most participants reported being African-American/Black (7) or White/Caucasian (7); two reported being Hispanic or Latino/a. All workers had been using digital procedures for several months. This study complied with the American Psychological Association Code of Ethics and was approved by Texas A&M University's Institutional Review Board. Informed consent was obtained from each participant.

2.2. Measures

All measures are included in Appendix A (in online supplemental material). Davis' (1989) 11-item TAM measure was used to assess perceived usefulness and ease of use. This measure has been used extensively in the TAM literature. In order to demonstrate validity evidence for the scores on the study measures, we performed exploratory factor analyses (EFA) on the full TAM measure including all (11) perceived ease of use (six) and usefulness items (five). The results of the EFA suggested that a *3-item* perceived ease of use and a *3-item* perceived usefulness measure be used to test our hypothesized relationships. Indeed, an analysis of the scree plot suggested a two-factor solution, however we eliminated items from the original measure due to substantial cross-loading of items on each dimension. Furthermore, there was not a substantial reduction in the internal consistency reliability with the reduction in items (ease of use final α = .96; usefulness final α = .94).

The same operators were also asked to complete Van Der Laan et al.'s (1997) technology acceptance measure. The operators were prompted with "I find digital procedures __________" and selected a button corresponding to a range of descriptors for two dimensions: usefulness (α = .90) and satisfaction (α = .80).

The current study was part of a larger data collection effort, and participants were also interviewed about a number of issues with procedures (see Mendoza et al., 2020). In an effort to understand why individuals were not accepting of the digital procedures, we identified those that scored lowest on Van Der Laan et al.'s (1997) measure. We then examined those individuals that responded to the following interview item: "Have you ever experienced transition from paper-based to digital procedures for a task? If yes, can you describe the transition for one of those tasks?"

Finally, attitudes toward procedures and deviation frequency were assessed with measures developed by Hendricks and Peres (2021). These measures included five items for utility attitudes toward procedures, two items for compliance attitudes toward procedures (we changed one item for compliance attitude in an attempt to increase reliability), and three items for deviation frequency.

2.3. Procedures

Participants provided consent for this study as part of a larger data collection effort that focused on a number of issues related to digital procedures. These included the aforementioned measures. We employed the Qualtrics® online survey platform to administer all demographic and Likert-scale items, including the TAM dimensions, the two attitudinal dimensions, the deviation items, and Van Der Laan et al.'s (1997) measure. Survey administration began after workers completed a shift. Accordingly, we asked participants to think about the task they had just performed at the end of their shift. These workers performed very similar logistics tasks (see above for self-reported task descriptors). For example, railcar loading tasks included loading products onto the railcar loading tanks.

2.4. Data Analytic Strategy

We used ordinary least squares (OLS) path analyses, including only the structural relationships, to test the study hypotheses. Each regression model included the relevant endogenous and exogenous variables. We also evaluated the fully saturated models for each endogenous variable and compared that model with the unsaturated model (see Pedhazur, 1997). The R^2 values for the models were compared to determine if the hypothesized (or reduced) model was a better fit than the fully saturated model.

In addition to the inferential statistical analysis, our plan was to examine the descriptive results of Van Der Laan et al.'s (1997) measure, identify individuals who had low scores on those responses, and report issues with technology acceptance they may have had in the aforementioned larger data collection effort that included interviews (see Mendoza et al., 2020). This approach was an attempt to incorporate some qualitative analysis to supplement the quantitative results. Again, we sought to provide more granular contextual information as to why individuals were relatively unaccepting of the digital procedures.

3. Results

3.1. Hypothesis Testing

The results of the path analysis are depicted in Figure 2. Four of the six study hypotheses were supported by the data. Indeed, perceived usefulness (PU) significantly predicted both attitudes toward procedure utility (β = .53, p = .014; Hypothesis 1 supported) and attitudes toward procedure compliance (β = .81, p < .001; Hypothesis 2 supported). Higher perceived ease of use (PEU) scores were associated with better procedure utility attitudes (β = .42, p = .039; Hypothesis 3 supported) but did not significantly predict compliance attitudes (β = .07, p = .765; Hypothesis 4 not supported). The total variance explained (adjusted R^2) in these two models was 70.8% for utility attitudes and 62.6% for compliance attitude.

Moving toward the ultimate endogenous (or criterion) variable in the proposed model, deviation frequency was significantly predicted by compliance attitudes (β = −0.84, p = .017; Hypothesis 5 supported), but not by utility attitudes (β = .51, p = .122; Hypothesis 6 not supported). Specifically, higher compliance attitude scores were associated with fewer reported deviations. We retained the hypothesized model for deviations since the R^2 value was higher for the hypothesized model (utility attitude included) vs. the reduced model (utility attitude not included). We also compared the variance explained by the fully saturated model with deviations as the endogenous variable and both TAM dimensions and attitudinal variables were included. The hypothesized model adjusted R^2 was smaller for the fully saturated model (adjusted R^2 = .25) than the hypothesized model (adjusted R^2 = .27).

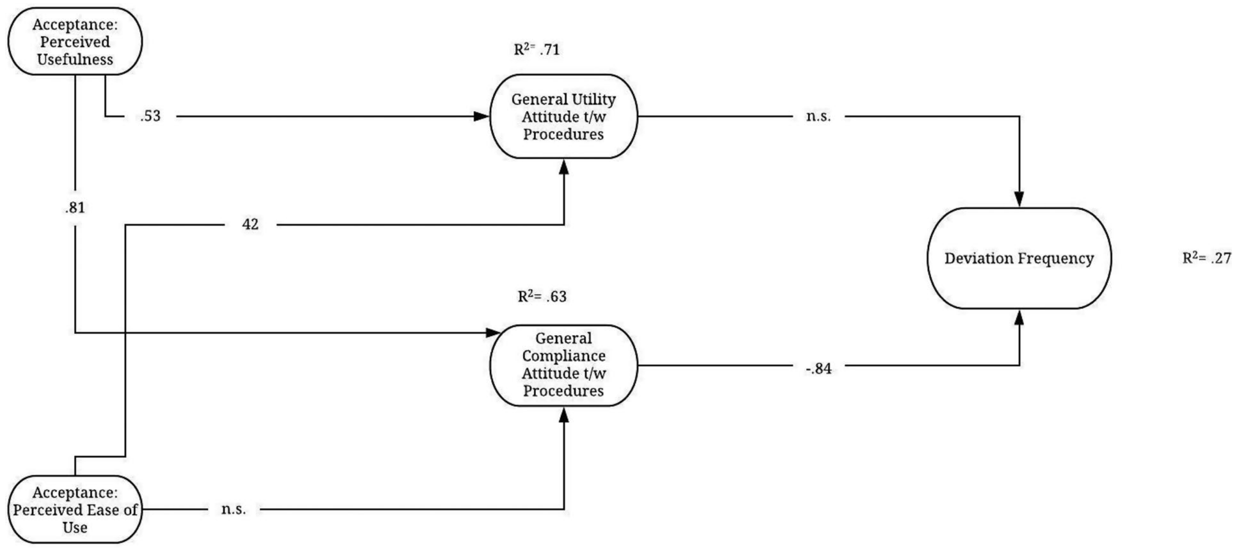

Figure 2. Depiction of study results of hypotheses tests for TAM dimensions, attitudes, and deviations. Values on the lines are standardized regression coefficients.

The second analysis focused on the responses to Van Der Laan et al.'s (1997) measure and the responses to the interview items. The mean usefulness score from operators was 1.08 (range: −2–2), signifying that operators thought that the digital procedures were useful. However, three operators had lower mean usefulness scores (one of -0.4 and two scores of 0). Based on the interview responses, the operator who had a mean score of −0.4 was concerned with the durability of the tablet in the field and the inconvenience of having to charge the tablet which may disrupt tasks. One of the operators who had a mean score of 0 mentioned that the tablets are heavier and harder to carry than the paper procedures. The other operator who had a mean score of 0 stated that they were mainly concerned with the use of digital procedures in emergency settings and the possibility of a system timeout or missing information when it is critical.

The mean satisfaction score for operators was 0.81, signifying that operators thought the use of digital procedures, on average, was satisfactory. However, the same three operators who had lower mean usefulness scores also had low scores for satisfaction (-0.75, −0.5, and −0.25). The operator whose mean score was −0.75 mentioned that they are not computer literate, preferred paper procedures over digital, needed more training on the digital procedures, and thinks there is too much tracking and oversight from the company, in addition to their comments on usefulness. The operator with a mean score of −0.5 did not have additional comments to their thoughts that the tablets can be heavy and hard to carry. The last operator with a mean score of −0.25 had no additional comments to their concerns with use of digital procedures during emergency situations.

4. Discussion

There are two prongs of results to discuss from this study. Each makes its own contribution to both the technology acceptance and process safety/procedures domain. First, the findings suggest that if individuals accept digital procedures based on their perceived usefulness, they will be more likely to develop positive attitudes toward procedure utility and compliance. Further, if individuals accept digital procedures based on ease of use, they will have more positive attitudes toward procedure utility, but not compliance. Finally, individuals are less likely to deviate from procedures based on better attitudes toward procedure compliance, but not utility. These results support four of the six study hypotheses. Second, taking a qualitative approach, all measures suggest that this sample was generally accepting of the digital procedure rollout, with the exception of a few workers. The reasons for low acceptance were primarily associated with hardware issues.

4.1. Research Implications

Although there was not support for all of the hypotheses, we developed and found support for a viable model that is consistent with Davis' (1986) and Davis et al.'s (1989) initial technology acceptance model and other empirical work in the TAM domain (e.g., Park, 2009). Indeed, there was an indirect effect between perceived usefulness and subsequent behavior—deviations—by way of compliance attitudes. Additionally, there was a direct effect between both acceptance constructs (PEU/PU) and utility attitudes toward procedures. These findings provide evidence for the validity of the TAM in the process safety domain, more specifically with regard to digital procedure adoption. Additionally, we replicated Hendricks and Peres' (2021) finding that compliance attitude predicts deviations.

However, the hypothesized TAM in this study was not fully supported by the data. We speculate there are non-trivial, conceptually substantive reasons why this may have occurred. The first is the lack of relationship between perceived ease of use and compliance attitudes. We speculate that the reason perceived ease of use of the digital technology did not impact general compliance attitudes toward procedures is that variation in these attitudes could be driven more by: (a) the content of the procedure, rather than the method in which it is presented (in this case, the digital format); and (b) other key system variables such as safety climate may be larger contributing factors. Low PEU with regard to the medium (digital vs. paper) is a relatively large .hurdle to clear (i.e., would really have to be difficult to use) in terms of reasoning for poor compliance attitudes that are impacted first by what allows them to successfully and safely complete the task in the first place—the content. This very well could be moderated by safety climate, which includes what is valued and rewarded (or punished) in terms of policies and practices in a work unit with regard to safe behavior. In poorer climates, ease of use of new technology might covary with compliance attitudes—the introduction of technology that is easy to use could result in better general compliance attitudes, but in better climates workers may hold the same compliance attitudes regardless of ease of use because compliance is what is valued and rewarded. Either way, these were not testable in the current study because we did not measure safety climate and should be considered in future research.

Accordingly, we propose that when adopting new technology within the procedures domain, there is likely at least one critical distinction to be made that has been somewhat ignored. This distinction is between medium and content. The TAM seemingly does not provide for this distinction, but they are very much extricable. When digital procedures are introduced, acceptance is a key factor for adoption, but if for example, the content is already not viewed favorably, the acceptance of the new technology is not nearly as important as it otherwise would be. Indeed, what may be affecting acceptance is the tool content, not the medium (or technology). These should be parsed moving forward in this line of research.

Another meaningful distinction that likely influenced the results is the focal behavioral dependent variable used. For instance, the lack of relationship between general utility attitudes and deviations could be that actual *procedure use* should have been used as the DV in this portion of the model. Hendricks and Peres (2021) provided evidence for—and made a conceptual distinction between—these two constructs and found a different pattern of relationships (i.e., antecedents/predictors with DVs) based on whether or not the dependent variable was deviation frequency (e.g., skip steps) vs. use (e.g., I don't look at/don't use procedures). As previously mentioned in the introduction, deviations can be adaptive and there can be "positive" reasons for deviations. We suspect that the reason a higher R^2 value was not observed for deviations *is* because of the different reasons for deviations. By not considering adaptive vs. non-adaptive deviations, there is likely meaningful variance missing from this criterion. Further, given the lack of a relationship between utility attitudes and deviations, it may be more appropriate to include procedure use as the behavioral DV. In fact, the relationship pattern for these IVs and DVs was reversed in Hendricks and Peres (2021)—utility was more strongly related to use, whilst compliance was more strongly related to deviations. We suggest using both use and deviations in future TAM research and broader procedure-related research as well.

Based on the interview responses, it may be necessary to expand the TAM to identify foundational problems that exist (e.g., infrastructure). This seems like a floor vs. ceiling or necessary vs. sufficient problem. Although not everyone felt this way, it seems that more substantive evaluation of the software, interface, etc., may not even be considered or will not matter if these basic elements of the new technology are deficient.

4.2. Implications for Practice

The results of this study have implications for workers in the process safety domain. Since we provided evidence to support the TAM with digital procedures as *the* new technology, procedure system developers should consider using these measures *as* they develop new digital procedure systems. Cost considerations (time, money, training, etc.) are the primary driver of this concern. Completely adopting a new digital system and then implementing it without considering acceptance could prove to be rather risky since our study suggests perceived usefulness and ease of use impact attitudes toward procedures. Moreover, when an organization considers the relatively low cost of implementing these TAM measures, there may be great benefit if an organization is comparing multiple platforms. In other words, an initial risk mitigating strategy might be to compare multiple existing platforms and determine which ones are perceived to be most useful and easiest to use before proceeding further in the development process. Finally, if the development process spans a long period of time, acceptance could be measured at multiple time points.

Another consideration that may be warranted based on low acceptance interview responses is that when considering the adoption of new technology, there may be some bedrock factors that need to be evaluated before moving forward to a digital procedure system. Again, the biggest drivers of low acceptance ratings were hardware problems, not software or interface issues. Organizations should be sure they have appropriate infrastructure and consider the practical issues of carrying devices on which digital procedures may be displayed. Also, to what extent do workers perceive these systems to be a threat to successful completion of high-risk tasks and mitigating hazards, especially those that are not routine, are questions to consider when implementing a new digital procedure system. Finally, individual differences in knowledge, skills, and abilities should likely be considered before implementing a new system to better determine training needs prior to a digital roll-out. Indeed, a somewhat related construct—readiness to adopt—should not be an afterthought in this area (Parasuraman, 2000)

4.3. Limitations and Future Research

Sample issues including size and representativeness in terms of organizations, workers, and the procedures themselves are limitations to this study. The latter (representativeness) may very well be the most meaningful, because these findings may vary as a function of different *types* of digital procedures. The small sample size in this study is not trivial for statistical analysis, but the resulting large effect sizes suggest that the population effect size is large enough that even at modest sample sizes a statistically significant effect can be found (see Cohen, 1988). Additionally, given that acceptance likely changes much more dynamically in the early stages of implementation and then stabilizes, we suggest future research examine acceptance using longitudinal designs. As previously mentioned, future research may need to consider different TAMs in this domain based on the behavior that is of most interest—use or deviations (or some other behavior not considered).

More substantive future investigations need to develop measures that can distinguish between the content of procedures and the medium by which they are presented (fully interactive digital vs. limited interactive digital vs. paper). Indeed, the number of features incorporated into a digital procedure tool can vary widely and likely should be accounted for methodologically. Additionally, taking an even broader systems view, researchers should examine the extent to which contextual, individual-level, and other task-related variables may moderate the relationships between the TAM dimensions and compliance attitudes. On the other hand, we think the relatively narrow scope in this effort is prudent. To paraphrase Hu et al. (2020), deviations are inevitable and adaptations are necessary to safely achieve task goals safely. However, normalizing these variations can have a cumulative effect that can go unnoticed and put workers and organizations at risk. We again contend that it is this point that implies deviations of any form should be kept to a minimum and we can also envision model differences depending on the procedure-related behavior of interest, whether it be actual use or deviations from the procedures.

Finally, future research—and this applies to any research where procedure-related behavior is examined—should not only examine deviation frequency, but also determine why workers are deviating from procedures.[2] Digital procedures are an ideal medium to have "adaptive procedures" where *what* procedure users see and *how* they see it changes as a function of task, person, and context characteristics. For example, a task performed infrequently by an inexperienced worker may call for highly detailed procedural steps that demand sign-offs whilst a routine task performed by a highly experienced worker can be more streamlined. More broadly, since workers are at times forced to be adaptive, it would be advantageous to have procedures that can support the system variability often encountered by workers. Our view is that as the procedural system becomes more complex, technology acceptance becomes even more critical for development of these tools. We view the current work as the first of several steps to develop more comprehensive models that will gauge the relative impact of technology acceptance in the process safety domain.

Notes

1. We wish to thank an anonymous reviewer for their comments related to this issue.
2. We wish to thank an anonymous reviewer for their comments related to this issue.

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Conflict of Interest

The authors declare no conflict of interest. The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official views of all of the NGAP members.

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References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alper, S. J., Holden, R. J., Scanlon, M. C., Kaushal, R., Shalaby, T. M., & Karsh, B. T. (2007). Using the technology acceptance model to predict violations in the medication use process. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *51*(11), 745–749. Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177/154193120705101130

Alper, S. J., & Karsh, B. T. (2009). A systematic review of safety violations in industry. *Accident; Analysis and Prevention*, *41*(4), 739–754. https://doi.org/10.1016/j.aap.2009.03.013

Amyotte, P. R., Goraya, A. U., Hendershot, D. C., & Khan, F. I. (2007). Incorporation of inherent safety principles in process safety management. *Process Safety Progress*, *26*(4), 333–346. https://doi.org/10.1002/prs.10217

Ashraf, A. M., Son, C., Peres, S. C., & Sasangohar, F. (2021, September). Navigating operating procedures in everyday work in a petrochemical facility: A comparative analysis of WAI and WAD. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 65, No. 1, pp. 623–627). Sage CA: Los Angeles, CA: SAGE Publications.

Ashraf, A. M., Peres, S. C., & Sasangohar, F. (2022, September). Investigating a new classification to describe the differences between Work-As-Imagined and Work-As-Done. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 66, No. 1, pp. 1805–1808). Sage CA: Los Angeles, CA: SAGE Publications.

Bullemer, P., & Laberge, J. C. (2010). Common operations failure modes in the process industries. *Journal of Loss Prevention in the Process Industries*, *23*(6), 928–935. https://doi.org/10.1016/j.jlp.2010.05.008

Carim, G. C., Jr, Saurin, T. A., Havinga, J., Rae, A., Dekker, S. W., & Henriqson, É. (2016). Using a procedure doesn't mean following it: A cognitive systems approach to how a cockpit manages emergencies. *Safety Science*, *89*, 147–157. https://doi.org/10.1016/j.ssci.2016.06.008

Chemical Safety and Hazard Investigation Board. (2017). ExxonMobil Torrance Refinery Electrostatic Precipitator Explosion, 1–73. https://www.csb.gov/exxonmobil-refinery-explosion-/

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

CSB. (2016). *Investigation report: Explosion and fire at the Macondo well.* Volume 2, U.S. Chemical Safety and Hazard Investigation Board.

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: Theory and results* [Doctoral Thesis]. Cambridge, MA: Massachusetts Institute of Technology.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982–1003. https://doi.org/10.1287/mnsc.35.8.982

Dekker, S. (2003). Failure to adapt or adaptations that fail: contrasting models on procedures and safety. *Applied Ergonomics*, *34*(3), 233–238.

Dou, K., Yu, P., Deng, N., Liu, F., Guan, Y., Li, Z., Ji, Y., Du, N., Lu, X., & Duan, H. (2017). Patients' acceptance of smartphone health technology for chronic disease management: A theoretical model and empirical test. *JMIR mHealth and uHealth*, *5*(12), e7886. https://doi.org/10.2196/mhealth.7886

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* Addison-Wesley.

Hale, A., & Borys, D. (2013). Working to rule, or working safely? Part 1: A state of the art review. *Safety Science*, *55*, 207–221. https://doi.org/10.1016/j.ssci.2012.05.011

Hendricks, J. W., & Peres, S. C. (2021). Beyond human error: An empirical study of the safety Model 1 and Model 2 approaches for predicting workers' behaviors and outcomes with procedures. *Safety Science*, *134*, 105016. https://doi.org/10.1016/j.ssci.2020.105016

Hollnagel, E. (2018). Safety-I and safety-II: The past and future of safety management. CRC press.

Hu, X., Casey, T., & Griffin, M. (2020). You can have your cake and eat it too: Embracing paradox of safety as source of progress in safety science. *Safety Science*, *130*, 104824. https://doi.org/10.1016/j.ssci.2020.104824

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management*, *43*(6), 740–755. https://doi.org/10.1016/j.im.2006.05.003

Kulp, L., Sarcevic, A., Farneth, R., Ahmed, O., Mai, D., Marsic, I., & Burd, R. S. (2017). Exploring design opportunities for a context-adaptive medical checklist through technology probe approach. *2017 Conference on Designing Interactive Systems*. https://doi.org/10.1145/3064663.3064715

Mathieson, K. (1991). Predicting user intentions: Comparing the technology acceptance model with the theory of planned behavior. *Information Systems Research*, *2*(3), 173–191. https://doi.org/10.1287/isre.2.3.173

Mendoza, A. M., Liu, S. N. C., Dumlao, S. V., Hendricks, J. W., Son, C., Sasangohar, F., & Peres, S. C. (2020). Where two ends meet: Operator and stakeholder perceptions of procedures. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *64*(1), 1350–1354. Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177/1071181320641322

Parasuraman, A. (2000). Technology Readiness Index (TRI) a multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research*, *2*(4), 307–320. https://doi.org/10.1177/109467050024001

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Journal of Educational Technology & Society*, *12*(3), 150–162.

Pedhazur, E. J. (1997). Structural equation models with observed variables: Path analysis. *Multiple Regression in Behavioral Research: Explanations and Prediction, 3rd ed.* Belmont, Calif, Wadsworth, 765–840.

Van Der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C: Emerging Technologies*, *5*(1), 1–10. https://doi.org/10.1016/S0968-090X(96)00025-3