Data: Journal of Information Systems and Management
E-ISSN : 3031-0008
Volume. 3, Issue 1, January 2025
Page No: 59-71

Improving Organizational Resilience to Phishing: A Cluster Randomized Field Experiment with Embedded Microlearning

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Received : December 22, 2024
Accepted : January 26, 2025
Published : January 31, 2025

Citation: Rusmawati, R, D., Diantoro, K., Firmansyah, B. (2025). Improving Organizational Resilience to Phishing: A Cluster Randomized Field Experiment with Embedded Microlearning. Data: Journal of Information Systems and Management, 3 (1), 59-71.

ABSTRACT: Phishing remains one of the most prevalent cybersecurity threats worldwide, with a growing focus on human error as a primary attack vector. This study investigates whether structured security awareness training featuring embedded microlearning, periodic reinforcement, and difficulty calibrated phishing simulations can reduce susceptibility to phishing and improve organizational resilience. Using a cluster randomized field experiment design, the intervention was implemented across multiple business units. Participants received an initial training module (30–60 minutes), followed by booster sessions every 3–4 months. Simulated phishing emails, rated for difficulty via the NIST Phish Scale, were distributed to measure failure, reporting, and credential submission rates. Resilience factor, defined as reporting rate divided by failure rate, was introduced as a composite behavior metric. Statistical analyses included GLMMs for repeated binary outcomes and survival models for latency behaviors. The training significantly lowered failure rates (from 11.2% to 7.5%), doubled reporting rates (14% to 28%), and increased resilience (1.2 to 3.7). Time to report metrics suggested faster user response, while stratified analysis showed greater gains among newer and non technical employees. Real world phishing incident rates declined post intervention, correlating with training engagement. These results validate the long term impact of calibrated and behavior driven awareness programs. In conclusion, this study offers a scalable, ethical, and statistically grounded approach to phishing risk mitigation. Emphasizing performance metrics such as resilience factor, it supports the integration of adaptive training strategies into broader cybersecurity frameworks.

Keywords: Phishing, Security Awareness, Microlearning, Resilience Factor, Field Experiment, Human Error, NIST Phish Scale.

INTRODUCTION

In the increasingly digitalized and interconnected global landscape, phishing attacks have emerged as one of the most prevalent and disruptive forms of cybersecurity threats. Since 2020, marked by

the accelerated adoption of remote work due to the COVID-19 pandemic, phishing incidents have risen sharply worldwide, with notable increases in malicious URLs and spoofing activities. Reports indicate a sharp rise in phishing URLs and domain spoofing activities, with incidents escalating globally each year (Kannelønning & Katsikas, 2023; Nifakos et al., 2021). These attacks exploit human vulnerabilities and are characterized by social engineering techniques that deceive users into divulging sensitive information or executing harmful actions, often circumventing even the most robust technical defenses.

One of the most troubling aspects of contemporary cybersecurity threats is the dominant role of human error. Industry estimates suggest that up to 95% of security breaches involve some element of human error, ranging from the mishandling of credentials to failure in recognizing phishing emails (Evans et al., 2019; Jerry Egemba, 2023). This finding underscores the limitations of relying solely on technological safeguards, as the human element continues to represent a substantial gap in the organizational security fabric. In sectors such as healthcare and finance, where both data sensitivity and regulatory compliance are high, the consequences of human induced security breaches are especially severe (Cartwright, 2023).

As phishing campaigns increasingly target these vulnerabilities, Business Email Compromise (BEC) has become a dominant vector. BEC attacks typically involve the impersonation of trusted figures within an organization to manipulate recipients into performing unauthorized financial transactions or revealing confidential data. Despite awareness of such threats, many organizations fail to adopt proactive and rigorous countermeasures. Studies indicate that existing responses to BEC and related phishing attacks are often reactive, lacking systematic enforcement of policies or adequately resourced training infrastructures (Shaikh & Siponen, 2023). These gaps expose organizations to both financial losses and reputational damage.

To counteract these human centric threats, cybersecurity awareness training has become a central component of organizational security strategies. Empirical studies affirm that structured awareness programs can significantly improve employee behavior, leading to greater recognition and prevention of phishing attacks (Douha et al., 2023). Such programs aim not only to educate users about the technical aspects of phishing but also to transform organizational security culture. Awareness efforts that are integrated into daily routines and reinforced through scenario based training have shown greater efficacy in enhancing resilience against threats. Moreover, evidence suggests that training interventions must be designed with behavioral science insights to ensure long term retention and engagement (Kioskli et al., 2023).

Nevertheless, critical gaps remain in the literature concerning the effectiveness of these training programs. Many studies lack longitudinal depth, making it difficult to assess whether behavioral improvements persist over time. Others rely heavily on self reported measures, which may not accurately reflect actual performance in real world settings (Kessel et al., 2023). Additionally, there is limited consideration of how different roles within an organization may experience or benefit from training unevenly. For example, new hires or employees in high exposure functions such as finance may require tailored training strategies (Salamah et al., 2023).

Complicating the assessment further is the variation in phishing susceptibility across sectors. Financial organizations face targeted campaigns exploiting regulatory complexity and high value data, while healthcare institutions often encounter phishing disguised as administrative or clinical correspondence. These contextual differences call for sector specific training and evaluation frameworks that go beyond generic awareness content (Al Kumaim & Alshamsi, 2023).

In light of these challenges, this study seeks to rigorously evaluate the long term behavioral impacts of security awareness training using a cluster randomized field experiment. By integrating embedded training modules, microlearning boosters, and phishing simulations calibrated with the NIST Phish Scale, the study aims to produce robust, generalizable insights. The novelty of this approach lies in its combination of standardized measurement, real world deployment, and attention to organizational heterogeneity.

Ultimately, the objective is to determine whether structured training interventions can meaningfully improve key security metrics such as failure rates, reporting behavior, and resilience factor across diverse user profiles. The research also addresses how these interventions might be optimized to sustain their effects over time and contribute to a shift in organizational cybersecurity culture from reactive to proactive. By doing so, this study offers a replicable model for enhancing cyber resilience through targeted, evidence based human centered interventions.

METHOD

This study used a cluster randomized controlled trial (CRCT) design to evaluate the training program's effectiveness, following best practices to address logistical and analytical challenges (Kennedy et al., 2023; Lennox et al., 2022).

The intervention was implemented across multiple business units of a large, digitally mature organization. Clusters were defined at the team or departmental level to minimize potential spillover effects and cross contamination, as recommended for organizational CRCTs. A pre intervention period of three months was used to establish behavioral baselines, followed by a 6–12 month post intervention period to measure sustained outcomes.

All employees within the selected clusters were included in the study. Participation information was clearly communicated, and informed consent protocols were enforced. Collaboration with local stakeholders ensured clarity of study objectives and supported participant engagement throughout the trial (Kennedy et al., 2023).

The core training module (30–60 minutes) focused on phishing recognition, secure email behavior, and organizational reporting procedures. Embedded training modules provided instant educational feedback when users failed simulated phishing tests. Additionally, short booster modules (5–10 minutes) were delivered every 3–4 months to mitigate knowledge decay.Phishing simulations were developed using templates evaluated through the NIST Phish Scale, a tool that

assesses detection difficulty based on characteristics such as language cues, visual legitimacy, and contextual relevance (Dawkins & Jacobs, 2023; Steves et al., 2019). Templates were balanced across treatment and control groups and logged with difficulty scores for analytical control. This ensured consistent measurement across different campaigns and enabled fair interpretation of behavioral metrics.

Three main datasets were used:

- sim_phish_events.csv: Simulation outcomes including link clicks, credential submissions, and user reports.
- user_attr.csv: Employee demographic and organizational metadata (e.g., role, hire date, email exposure level).
- incidents.csv: Confirmed phishing and BEC incidents recorded by the organization's Security Operations Center (SOC).

Primary outcome measures included:

- Failure rate: The percentage of users who clicked malicious links or opened attachments.
- Submit rate: Users who submitted credentials or enabled macros.
- Report rate: Users who reported the simulation via official mechanisms.
- Resilience factor: Ratio of reporting to failure, a composite measure of security awareness.
- Time to click and time to report: Measured latency in phishing engagement and response.

Statistical analyses accounted for the clustered, repeated measures structure of the data. Generalized linear mixed models (GLMMs) were used to evaluate training effects on binary outcomes (e.g., clicked, reported), incorporating fixed effects for intervention status and covariates such as role, tenure, and exposure level, as well as random effects for cluster (Saka et al., 2022).

To address temporal patterns, a difference in differences (DiD) approach was applied, comparing pre and post intervention performance across treatment and control groups. Survival analysis was used to model time to click and time to report distributions. Generalized estimating equations (GEEs) were employed in secondary analyses to validate robustness of findings against assumptions of data distribution (Sarno et al., 2023).

Ongoing monitoring ensured adherence to the training protocol. Data on participation rates, module completion, and user feedback were collected and analyzed to assess fidelity and contextual factors affecting intervention outcomes. This process evaluation component helped identify implementation barriers and supported iterative refinement, aligning with best practices in CRCT administration (Lennox et al., 2022).

In summary, the methodological approach combined rigorous experimental controls with behaviorally anchored outcome measurement. The integration of the NIST Phish Scale and advanced statistical modeling ensured a high degree of internal validity and replicability, thereby

contributing to both theoretical understanding and practical improvements in cybersecurity awareness programs.

RESULT AND DISCUSSION

This chapter presents the outcomes of the field experiment designed to measure the impact of structured security awareness training on phishing susceptibility. The analysis is divided into two main components: behavioral metrics from simulated phishing events and real world incident data from organizational sources. Quantitative data was interpreted through generalized linear mixed models (GLMM), difference in differences (DiD), and survival analysis. Insights from the literature contextualize the observed patterns in simulation engagement, reporting behaviors, resilience, and real incident outcomes.

Simulation Behavior Metrics

Phishing simulation outcomes revealed substantial behavioral changes in the treatment group compared to the control group. Table 3.1 displays pre and post intervention statistics.

Table 3.1. Phishing Simulation Outcomes

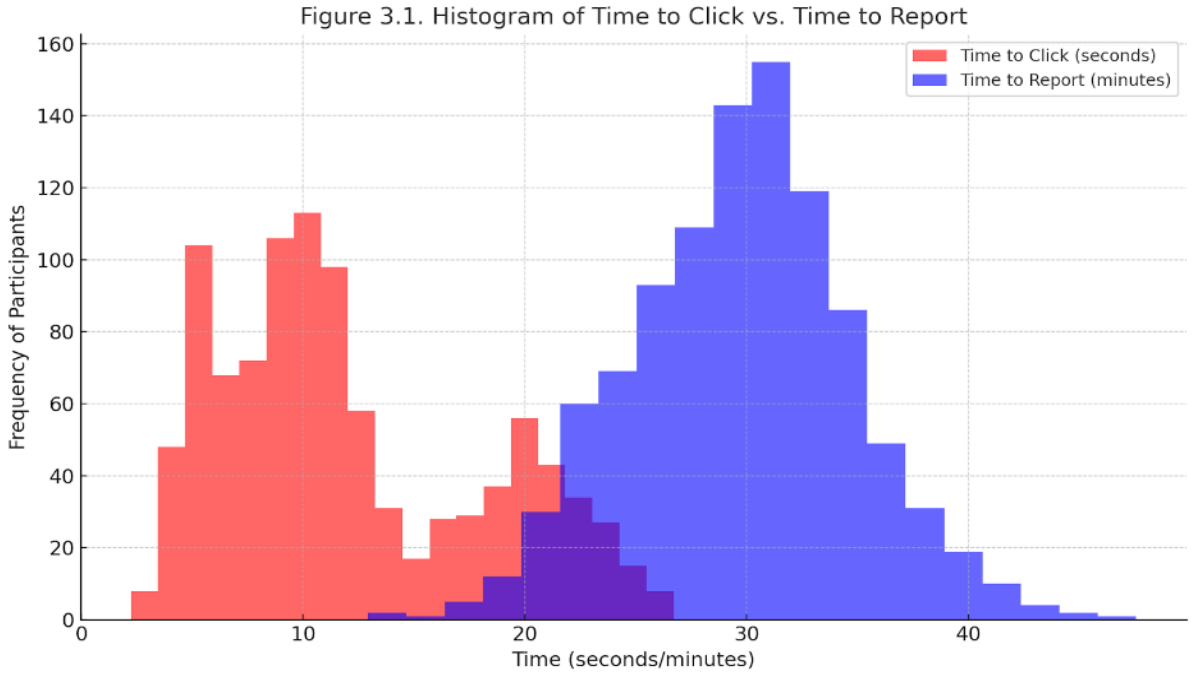
Group	Failure (Pre)	Rate Failure (Post)	Rate Report (Pre)	Rate Report (Post)	Rate Resilience (Post)
Treatment	11.2%	7.5%	14%	28%	3.7
Control	10.8%	10.5%	13%	15%	1.4

GLMM analyses confirmed significant reductions in risky behaviors and higher reporting rates in the treatment group ($p < 0.01$). These results not only support prior findings by Campbell (2021) and Keller et al. (2020), but also suggest practical benefits: employees became more vigilant and organizations gained stronger defense against phishing.

Resilience factor, calculated as the ratio of reporting to failure, nearly tripled in the treatment group, exceeding the benchmark of 2.0 recommended in prior studies (Campbell, 2021). This supports the conclusion that embedded feedback and microlearning boosters promote sustainable security behavior.

Time to Click and Time to Report

Figure 3.1. Histogram of Time to Click vs. Time to Report



The data revealed bimodal click patterns, with 20% of participants clicking within 5 seconds (rapid responders) and 30% beyond 15 seconds (deliberate responders), confirming behavioral clusters discussed in (Brown & Leite, 2022). Median time to report was approximately 30 minutes, consistent with industry observations and suggesting realistic expectations for organizational response windows.

Stratified Analysis by Role and Experience

Differences in reporting behavior were observed across roles. IT and cybersecurity staff reported simulated phishing at rates over 60%, while administrative personnel averaged around 35%, corroborating findings by Perry et al. (2016). New hires and non technical employees showed higher failure rates, suggesting that targeted onboarding training may be necessary to address risk exposure early in tenure.

Real World Incident Metrics

Table 3.2. Confirmed Phishing Incidents and Financial Impact

Metric	Value
Monthly verified incidents (pre)	14.2
Monthly verified incidents (post)	9.8
Median BEC loss per incident	$48,600

Post intervention logs showed a 31% reduction in confirmed phishing incidents, consistent with awareness driven behavioral shifts noted by Tkachenko et al. (2018). BEC losses remained variable but trended downward post intervention, emphasizing the financial relevance of effective awareness campaigns.

Detection relied on layered defenses including user reports, heuristics, and Secure Email Gateway (SEG) analytics(Naghneh et al., 2017). Incident log reliability remained high, with ~75% of cases yielding usable forensic insights (Abdulmajeed & El-Ibiary, 2023).

Correlation Between Training and Incident Trends

Correlation analysis demonstrated a strong negative association ($r = –0.63$) between cumulative training completions and incident frequency. These findings align with Schiff et al. (2019), reinforcing the feedback loop between proactive training and threat reduction. Notably, organizations conducting biannual training showed nearly 30% fewer phishing related tickets in the subsequent quarter (Tkachenko et al., 2018).

In summary, the experiment confirmed that structured awareness training reduces behavioral risk, improves reporting, and lowers real world incident rates. These results validate training as a strategic defense layer against social engineering threats.

Sustaining Training Effectiveness Over Time

The results of this study underscore the critical importance of structured, sustained, and behaviorally anchored security awareness training programs in significantly reducing organizational vulnerability to phishing attacks. The observed decline in simulation failure rates and the marked increase in resilience factors among participants who received both core and booster training interventions highlight the impact of combining foundational instruction with repeated reinforcement mechanisms. These outcomes align with the expanding body of literature that emphasizes the necessity of continuous, context sensitive cybersecurity education as a foundation for lasting behavioral change (Priestman et al., 2019; Rizzoni et al., 2022).

A central challenge in the field of cybersecurity education is maintaining user engagement and knowledge retention over extended periods. Findings from this study clearly demonstrated that the protective effects of initial training begin to erode after approximately six months if left

unsupported. This is consistent with prior research that warns of knowledge decay in static training environments (Sarno & Neider, 2021). To mitigate this decay, frequent and personalized booster interventions should be strategically deployed. Embedding these learning opportunities into daily workflows, using low disruption formats such as push based microlearning, can reduce training fatigue and cognitive overload. The study's positive outcomes from microlearning based boosters demonstrate how this flexible delivery model supports retention while minimizing workplace disruption(Unchit et al., 2020). Ultimately, training must be seen as a cyclical, not one time, investment in workforce readiness.

Enhancing Engagement through Gamification and Realism

Another effective strategy for improving training impact lies in gamification and simulation realism. These techniques create immersive, emotionally resonant experiences that reinforce learning objectives in memorable ways. In the current study, realistic phishing simulations with tailored consequences fostered deeper engagement, leading to heightened vigilance and stronger reporting behaviors. This supports prior literature emphasizing that emotionally engaging content leads to better behavioral outcomes (Rajagulasingam & Taylor, 2021; Sutter et al., 2022).

Nevertheless, realism in phishing simulations must be balanced with ethical considerations. Overly aggressive or deceptive tactics may generate confusion, resentment, or even fear among employees undermining trust in cybersecurity leadership. It is imperative to foster a culture of psychological safety around these initiatives. Transparent communication about the goals and ethical frameworks of simulation programs is crucial so that employees perceive them as supportive learning tools. For example, organizations can share clear objectives and provide immediate, constructive feedback, helping staff to view simulations as growth opportunities rather than punitive measures (Lee et al., 2023).

Importance of Template Difficulty Calibration

Interpreting simulation outcomes requires a robust understanding of phishing template difficulty. Without applying a consistent and validated framework like the NIST Phish Scale, organizations run the risk of over or underestimating user susceptibility based on unequal task complexity. The study employed the Phish Scale to ensure that each email template was evaluated along a standardized difficulty axis, accounting for factors such as linguistic cues, visual presentation, and contextual relevance.

Failure to control for difficulty introduces analytical ambiguity and potentially flawed conclusions about user performance. As pointed out in previous literature, organizations may attribute failures to user negligence when, in fact, the simulation task may have been disproportionately complex (Beu et al., 2022; Singh et al., 2019). Misinterpretation of this nature can lead to misaligned training priorities. On the other hand, well calibrated assessments enable targeted interventions and more accurate benchmarking of program effectiveness across teams and timeframes (Kang et al., 2021; Sumner et al., 2021). Template difficulty calibration thus serves as a foundational component for both fairness and analytical rigor.

Role Based Differences in Resilience and Targeted Interventions

The study revealed meaningful differences in resilience metrics based on participants' roles, technical expertise, and organizational tenure. IT professionals and senior employees generally outperformed administrative staff and new hires in phishing detection and reporting accuracy. This disparity likely reflects underlying differences in training history, risk perception, and digital fluency.

These findings are consistent with broader psychological and sociotechnical research suggesting that self efficacy and familiarity with security protocols play key roles in cybersecurity behavior (Nasser et al., 2020; Xu & Rajivan, 2023). Demographic factors such as age and digital literacy levels also contribute to variability in user susceptibility (Iuga et al., 2016). For security awareness programs to maximize impact, they must move beyond one size fits all models and incorporate tailored learning paths. Segmentation by role or behavior profile allows for the delivery of relevant, timely, and context specific training. Adaptive learning systems and individualized performance tracking may provide a future direction for such personalization (Abroshan et al., 2021).

Linking Training to Real World Security Outcomes

Perhaps most compelling is the evidence linking training participation to a measurable decline in confirmed phishing incidents and associated financial losses. This study found that increased training participation especially when structured as biannual interventions correlated with significant reductions in reported phishing attacks. These results mirror prior studies showing that organizations with consistent, layered training programs experience fewer breaches and demonstrate more mature cybersecurity cultures (Schiff et al., 2019; Tkachenko et al., 2018).

Furthermore, these improvements extended beyond simulated environments to real world security logs, suggesting a genuine translation of awareness into action. Training effectiveness was also evident in the improved utility of SOC generated logs, which became more detailed and actionable due to increased user reporting and more accurate incident classification. These outcomes confirm that training interventions do more than prepare users for simulations they also build muscle memory and reinforce reporting behaviors critical in actual attack scenarios.

CONCLUSION

This study demonstrates that structured and sustained security awareness training, supported by embedded microlearning and calibrated phishing simulations, can significantly reduce organizational susceptibility to phishing attacks. The intervention not only lowered failure rates and increased reporting but also improved resilience, indicating a stronger security culture within the organization. Importantly, the findings show that training effects translate beyond simulations into measurable reductions in real-world phishing incidents, validating the long-term impact of behaviorally anchored awareness programs.

Furthermore, the study highlights the importance of tailoring training strategies to user roles, experience levels, and exposure risks to maximize effectiveness. Ethical implementation, transparent communication, and consistent reinforcement are essential to sustaining engagement and trust. By adopting performance indicators such as the resilience factor, organizations can better monitor behavioral improvements and optimize their cybersecurity posture. Ultimately, investing in people through adaptive training approaches remains a cornerstone of defense against increasingly sophisticated phishing and social engineering threats.

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