



The bomb crater effect under the influence of audit feedback: Now you see me, now you don't

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ABSTRACT

Safety-related rule violations in High Reliability Organizations have the potential to cause accidents, with severe consequences for people, organizations or even society. To prevent such accidents, safety audits are conducted to monitor and ensure high safety standards. In the area of finance, over the last decade, studies have investigated a counterproductive effect of tax audits, termed *the bomb crater effect*. This describes an increased tendency to evade taxes after a conducted audit. As underlying dynamic the *loss repair* is contrasted with the *misperception of chance*. Transferring these investigations to the field of process industries, we also investigated the bomb crater effect (and its promoting latent variables) after safety-related audits. Using WaTrSim, a simulated waste water treatment plant, we analyzed the data of 231 participants – trained as control room operators – regarding the impact of framed production outcomes and the effect of positive or negative audit feedback with financial punishments as a consequence of rule violations. We found strong evidence, that negative audit feedback and loss framing influence an operators tendency to violate safety rules after an audit.

1. Introduction

1.1. Safety-related rules and their violation

Safety issues are as old as mankind. Regulations to secure the wellbeing of laborers or any possibly affected persons can even be found in the bible. “When you build a new house, you shall make a parapet for your roof, that you may not bring the guilt of blood upon your house, if anyone should fall from it” (Deuteronomy, 22:8; [Bibles, 2008](#)). These lines also reflect an employer’s duty to secure employees’ safety and their responsibility to create a working environment that supports safety.

As today’s world is much more complex than in biblical ages, so too has the need for standards, rules and regulations increased. In modern industries, the violation of these safety rules has led to some of the most catastrophic manmade disasters. The roots of these disasters can be found on the operational level, like the Chernobyl accident in 1986 ([IAEA, 1992](#)), and on strategic levels, as was the case in the Fukushima Daiichi nuclear power plant disaster in 2011 ([National Diet of Japan, 2012](#)). Regarding the petrol processing industries, the Piper Alpha disaster in 1988 ([Paté-Cornell, 1993](#)) and the explosion and oil spill of Deepwater Horizon in 2010 were caused by a number of factors, with safety-related rule violations playing a decisive role ([CSB, 2016](#)). A

multitude of examples can also be found in the aviation industry, e.g. the mid-air collision in Überlingen, Germany, in 2002 ([Johnson, 2004](#)).

In an attempt to combat the risk of such incidents, since the 1980s, a research field focusing on high reliability organizations (HRO) has emerged. In these organizations, human error is closely linked to operations: Workers must work with a high level of reliability in the face of some of the most complex and risky working environments ([La Porte, 1996](#)). Rule violations are attributed to human error, which [Reason \(1990\)](#) differentiates in terms of content: In his concept, he divides rule deviations into intended and unintended actions. Rule violations are intended deviations from rules, but they differ from sabotage in that they are non-malevolent ([Reason, 1990](#)). In the goal conflict between safety and productivity, a large number of safety-related rule violations can be ascribed to deliberate rule violations, even in highly hazardous environments such as offshore oil rigs ([Paté-Cornell, 1993](#)).

2. Safety audit theory and research

Audits as they are implemented in many producing industries can be understood as consequence-based feedback interventions, as they are established in order to attain given targets and for a nominal-to-actual comparison ([Bergh et al., 2015](#)). In the context of this research we only refer to individual performance feedback in contrast to organizational/

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management audits. Feedback interventions may take place before an action (antecedent) or may be communicated as a consequence of an action, which is termed consequence-based feedback (Wilder et al., 2009). In the following, we use the term audit to refer to such consequence-based feedback.

Analyses of feedback-research from the beginning of the 20th century up to the 1970s suggested a general increase in the audited workers' performance (Kluger and DeNisi, 1996). However, according to Kluger and DeNisi (1996), this conclusion only applies to a selective sample of the investigated feedback intervention studies rather than reflecting an actual effect of the audits (consequence-based feedbacks). A broader consideration of investigations reveals that the effect of audits encompasses much more diverse reactions (to the audits) than merely increased performance. This variability can be explained by some action theories, which describe audit feedback as an action regulation issue. These theories describe actions, by definition, as goal-oriented (e.g. goal setting theory by Latham and Locke (1991) or control theory by Carver and Scheier (1981)). To reach an objective, audit feedback is used to provide information about the discrepancy between the actual and the desired target state with the aim of reducing this discrepancy. However, from the perspective of action regulation theory, increased performance is not the only possible behavioral adaptation brought about based on the information from the audit feedback. Further options for adapting actions are the reorganization of goals or ignoring the audit feedback in order to avoid unpleasant dissonance (Kluger and DeNisi, 1996).

Most audit investigations from the last decade can be found in the context of tax evasion, as will be shown in the next section. Tax reporting behavior is also considered as rule-related behavior, although there are no consequences for safety.

2.1. Audits and their consequences: the bomb crater effect

Besides a variety of intentions, audits are also implemented for safety to prevent unsafe actions (von der Heyde, 2015). Several studies on tax evasion identified an unintended byproduct of these audits, a phenomenon called the bomb crater effect. It describes a high number of rule violations directly after an audit (Mittone, 2006). Mittone used this term to refer to the behavior of soldiers in the First World War: Soldiers hid in bomb craters, as they estimated a lower probability of bombs detonating twice in the same place. Mittone (2006) attributes this to a misperception of chance, which might be the root of the bomb crater effect. Transferred to the context of safety audits, workers believe that it would be unlikely for two audits to be implemented in succession. However, over the last decade, this unintended effect has mainly been investigated in the context of tax evasion, and less in terms of rule violations in the safety context. **The aim of our study is to identify the underlying conditions that promote or prevent the occurrence of the bomb crater effect.** The existing body of literature regarding tax evasion discusses the misperception of chance in contrast to the effect of loss repair, as an underlying dynamic in the occurrence of the bomb crater effect (Mittone et al., 2017). Misperception of chance describes the confidence that the likelihood of events depends on previous events, which is apparently reflected in Mittone's description of soldiers' behavior. On the other hand, in the tax evasion context, this behavior can also be explained by loss repair, which describes the attempt to compensate previous losses due to detected evasion and subsequent fines by evading even more.

Due to the similarity with the objective of safety audits in terms of content, we also take into account findings from this research field. In the following, the studies cited are grouped into laboratory and field studies, as their results differ fundamentally with respect to the underlying dynamics that promote or prevent the occurrence of the bomb crater effect. To derive our hypotheses, we examined both types of investigation in order to determine relevant similarities or differences.

2.1.1. Laboratory studies

Financial psychology research on tax behavior reported by Mittone (2006) identified a counterproductive effect of audits on tax filing respectively tax evasion. In each of eight experiments (N = 240), the tendency to violate the rule (in terms of a correct tax report) rose directly after an audit. Stimulated by these findings, a series of investigations examined the effects of audits.

To investigate the underlying dynamics of the bomb crater effect, a study was conducted which focused on explaining the effect itself, and not on replicating or determining the robustness of the effect (Maciejovsky et al., 2007). This study tested two common biases: (a) the misperception of chance and (b) loss repair.

It emerged that different audit probabilities led to different behaviors after a conducted audit. However, there was no difference in behavior after a negative audit (violation identified) compared to the behavior after a positive audit (no violation identified). The authors concluded that the misperception of chance plays a more substantial role in the emergence of the bomb crater effect than loss repair (Maciejovsky et al., 2007). Nevertheless, the method of analysis did not completely erase any doubts about how the bomb crater effect emerges, as it directly compared the number of rule violations (in this context: tax evasion) after a positive and negative audit. To shed more light on the underlying dynamics, we suggest comparing the delta of violations before and after an audit, separated by the result of the audit (positive or negative).

Maciejovsky et al. (2007) employed a different method of analysis, and concluded that an adapted behavior after a negative audit can be attributed to loss repair (Kastlunger et al., 2009). The authors did not directly compare the amount of tax evasion after a positive audit with the amount after a negative audit, but rather conducted a regression analysis between the amount of fines (as a result of a detected tax evasion (negative audit)) and the subsequently evaded taxes. The evasion after the negative audit was explained by a loss compensation, which suggests bias of loss repair.

A study examining tax liability focused on the factor of reward as a result of positive audit feedback (Seidl, 2009). The author noted that even a reward for tax compliance does not lead to a reduction in the bomb crater effect. However, the study was unable to provide any insights into the underlying dynamics of the bomb crater effect, as it did not differentiate between positive and negative audit feedback. Although reduced tax compliance was observed after an audit, the question of why a reward did not reduce the bomb crater effect was not addressed.

The reported studies by Mittone (2006), Maciejovsky et al. (2007), Kastlunger et al. (2009) and Seidl (2009) demonstrated a robust bomb crater effect. In contrast, Choo et al. (2013) described the bomb crater effect as an artifact of the implemented study designs. In their online study, participants had to carry out a simple task to earn their remuneration. After each of 12 trials, they had to report their taxable income, having been previously informed of the probabilities of an audit (5%, 20% and 40%). The authors compared their sample of self-employed workers from different industries with a student sample from another study using the same experimental design, in which the bomb crater effect emerged. However, their conclusions may merely scratch the surface in terms of influencing factors: The compared samples differed not only in terms of the participants' working status, but also with regard to sample size (workers: 92, students: 500), examination method (workers: online-based, students: on-site laboratory setting), financial sensitivity (amount of disposable and lost money can have a different severity for workers and students), opportunity for tax evasion (students: feasible, workers: barely possible due to automated deductions). In particular, long-term experience of automated deductions might establish a tax-compliant mentality (Fonseca and Myles, 2012).

In our studies (deleted for review), participants were asked to operate a simulated waste water treatment plant (WaTrSim) to split the delivered waste water into water and solvent in order to earn

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