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Reconceptualising innovation failure

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ABSTRACT

This study examines the concept of innovation failure. It is a problematic subject without an accepted definition. For different stakeholders the same innovation can be both a success and a failure at the same time. The academic literature has concentrated on the determinants of innovation success. Yet, there is a notable lack of academic literature that deals with innovation failure as a topic in its own right. As a result, there is limited attention to, and little consensus on, the meaning of innovation failure. Existing definitions imply a highly contingent conceptualisation of innovation failure informed by the different theoretical framings and disciplinary interests of the researchers. We adopt a systematic literature review methodology that examines the concept of innovation failure at the level of the firm and from an innovation management perspective. The findings of this review are based on a total of 69 peer-reviewed articles from 1977 to 2021. We find the concept is widely used yet poorly defined and frequently lacks any theoretical underpinning. By means of a theory-building inductive synthesis our findings contribute to research by reconceptualising the concept of innovation failure along three processual dimensions: failure-as-*experimentation*; –*judgement* and -*event*.

1. Introduction

The majority of the studies purporting to analyse innovation failure seem to begin from a recognition that it has a widely accepted definition (Liao and Cheng, 2014; Rizova, 2006) and yet it often remains undefined. It also has many interpretations (Kitsios and Kamariotou, 2020; Rizova, 2006) and appears to be a multifaceted concept. Success and failure are not necessarily opposite nor are they a black and white issue (Ika, 2009). Failure can later become success, and so failure is a transient state, or a temporary condition (Morais-Storz et al., 2020). Failure can also be a matter of opinion based on individual preference, and so for different stakeholders the same innovation can be both a success and a failure at the same time (Dudau et al., 2018). It seems innovation failure is a problematic concept.

For the past 100 years engineers, sociologists, historians, and economists have been theorising about technological innovation. In the last forty years a dominant view has developed which sees innovation as commercialised invention. Indeed, this has led to the development of the 'innovation studies' field of research (Godin, 2012). Here innovation is promoted as a solution to many problems and a generator of economic and social value. Yet, scholars recognise that most inventions do not become innovations, hence their call for improvements in the efficiency of innovation (Vinck, 2017).

Innovation failure is commonly described as something to be avoided (Bergek et al., 2008; Klein Woolthuis et al., 2005; van Mierlo et al., 2010). Understanding weaknesses in innovation systems, so the argument goes, can enable the development of national policies to "overcome that failure" (Jenson et al., 2016). The same argument is made at the company and project levels, where the presence of certain factors seems to be associated with success and failure (van der Panne et al., 2003). We recognise that it would be short-sighted to suggest that identifying the success factors would also reveal what determines innovation failure; and yet, as others (e.g. Pellegrino and Savona, 2017) have noted, the literature on firms' innovation failure is notably smaller than that which focuses on the determinants of innovation success. The work by Benoit Godin is a notable exception in the field of innovation studies. He observed that there were "few views regarding failure, and the absence of any conceptualization of failure dynamics and outcomes" (Godin and Vinck, 2017:10). Significantly he offers a useful critique of current representations of innovation as success, and argues that alternative ways of thinking, such as failure, are necessary for a full understanding of innovation.

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Innovation failure has been of interest to policy makers and scholars for many years. For example, Spiller and Teubal (1977) analysed failure in R&D projects forty-five years ago in Research Policy. Management research considers failure as an inevitable feature of innovation (Morais-Storz et al., 2020). In large organisations with large R&D budgets, innovation is frequently viewed within a portfolio, where the expectation is that some innovations will succeed, and some will fail, with the proportion of failures in line with the level of uncertainty. Within a portfolio model, there is a high acceptance of failure and an associated need to spread risk. Thus, in a portfolio model failure is taken as a given. At the project level however, the classical view is that firms should change behaviour after failure and increase the search for alternative approaches (Cyert and March, 1992; Leoncini, 2016; Van de Ven and Polley, 1992). Where projects were shelved due to unknown external factors such as a smaller-than-expected market, or an immature technology ecosystem, the classical learning model might not be appropriate. Nonetheless, the existing literature on innovation failure promulgates the importance of learning from it without stopping to examine the concept of failure itself.

The purpose of this systematic literature review is to examine the concept of innovation failure at the level of the firm and from an innovation management perspective. We aim to clarify the lines of debate surrounding innovation failure and to suggest new research activities as well as to structure scientific knowledge in this area. Our rationale for implementing a systematic literature review is informed by two main weaknesses in the current studies related to innovation failure. Firstly, the theoretical underpinning of innovation failure is undeveloped, and whilst the concept has many interpretations it also frequently goes undefined. Secondly, failure remains an essential feature in the pathway to innovation, but the concept itself is glossed over as the primary focus of studies are concerned with antecedents or consequences of failure. This review seeks to reinterpret the research literature, and thereby develop a new conceptual framework of innovation failure. In doing so this paper responds to calls (e.g. Scaringella, 2017; Vinck, 2017) that failure is studied with the same degree of diligence as innovation success.

Thus, by means of a theory-building inductive synthesis of the research literature we contribute a reconceptualisation of innovation failure along three dimensions: *failure-as-experimentation*; *–judgement;* and *-event*. We find that "failure" is treated in many empirical studies as some absolute state of affairs when, if a longer temporal perspective is taken, it is only ever provisional. *Failure-as experimentation* recognises the centrality of on-going testing of new ideas within innovation projects. *Failure-as-judgement* recognises that failure is often a matter of individual perspective, and we identify the "declaration of failure" as a proactive strategy used by managers as a means of initiating a distinctly new direction in the innovation process (Bartel and Garud, 2009; Rindova et al., 2011). Finally, *failure-as-event* recognises that unexpected shocks and crises can occur that impinge upon innovation projects and shape the subsequent management response.

The remainder of the paper is structured as follows: Section 2 provides a theoretical background to our study. Section 3 details the research methodology for our systematic literature review. Our findings and analysis are reported in Section 4, and we conclude with a discussion and research agenda in Section 5.

2. Theoretical background

In this paper we examine the meanings attributed to the concept of "failure" within the research literature on innovation management. Our aim is to generate a conceptual framework that shows the ways in which failure might be viewed as central for a full understanding of innovation. In this section we outline the broad literatures in which innovation failure appears. In our reading of these literatures, we note firstly an absence of consensus in the variety of definitions offered for 'innovation failure' and summarise these in Section 2.1. We argue that in empirical studies 'innovation failure' has been treated as the 'absence of success', with the consequence that the nature of failure itself is not critically examined and we discuss the implications of this success/failure dichotomy in Section 2.2. And finally, we discuss the literature on 'learning from failure' in Section 2.3, and argue that its theoretical emphasis is on organisational learning rather than failure.

Our overarching position is that failure is under-theorised within the innovation management literature: it is glossed over or taken-for-granted as research focusses on topics related to either "innovation" in its broadest sense, "innovation success" or "learning from failure". Fig. 1 offers a visual representation of our focus in this paper.

2.1. Existing definitions of innovation failure

When reading the literature examining the concept of innovation failure it quickly becomes apparent that there is little consensus on the meaning of this concept. Table 1 presents eight definitions of innovation failure evident within the extant literature. These definitions relate variously to the causes, consequences, and expectations of innovation projects. They are informed by the different theoretical framings and disciplinary interests of the researchers. Each of these definitions conceives failure as relating to an event that is particular to the context being studied, such as the failure of a technology or the termination of the project or the rejection by customers. Failure is often specifically related to a project phase, such as failure of the idea to attract investment (Rhaiem and Amara, 2021) or development failure (Marzocchi and Ramlogan, 2019). These definitions thus imply a highly contingent conceptualisation of innovation failure.

A closer reading of the research reveals that whilst some innovation failures are very clear-cut, the decision to terminate a project is often unclear, nuanced, difficult and complex (Green et al., 2003; Kumar et al., 1996). Importantly, in both clear-cut and complex cases failure is usually not theorised, but rather treated in a taken-for-granted manner: research participants consider something is a failure and their perspective forms the basis of the definition. These studies say *when* the innovation project was declared a failure, but they do not say *what* failure is. As a consequence, failure assumes a default meaning of "not-success". For example, in relation to financial returns "a success being defined as an innovation which obtains a worthwhile market share and profit, and a failure being defined as an innovation which fails to achieve this" (Rothwell et al., 1974, p.259). In the next section, we discuss the limitations of viewing innovation failure as "not success".

2.2. Failure as "not success"

The innovation management research literature has historically emphasised factors leading to success (Vinck, 2017). On the occasions in which failure and success are discussed together then failure is often conceptualised in relation to success. In a literature review of the factors contributing to the outcomes of innovation projects (van der Panne et al., 2003) innovation failure was (implicitly) conceptualised as the absence of success. Thus, for any factor that was identified as a contributor to success (e.g. adequate market research), the absence of

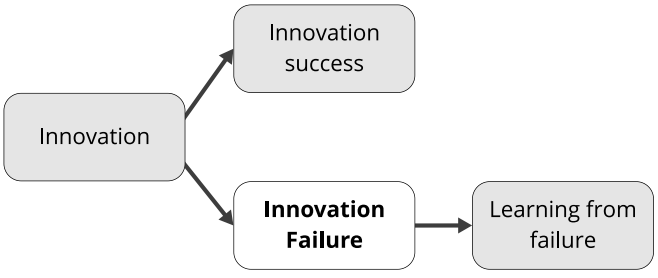

Fig. 1. Visual representation of the focus of this paper, with each box representing a body of extant literature.

Table 1
Existing descriptions of innovation failure.

	Types of innovation failure	Characteristics of this failure type	Illustrative research
1	Technology failure	Technical performance did not achieve expectations, e.g. poor prototype performance.	(Hyll and Pippel, 2016; Spiller and Teubal, 1977)
2	Termination of R&D project	The realization of unacceptably low performance in R&D projects that results in a managerial decision to terminate the activity, which can occur at any stage of the innovation development process.	(Green et al., 2003; Harrison, 2003; Shepherd et al., 2009; Shepherd and Kuratko, 2009; Shin et al., 2018)
3	Early consumer rejection	Lack of acceptance by consumers especially in early consumer testing.	(Chen et al., 2013; Rhaiem and Amara, 2021; Rothwell et al., 1974; Scaringella, 2017; Spiller and Teubal, 1977)
4	Project attrition failure	The deliberate decision to start multiple new product design projects in parallel, in the expectation that the majority will not meet expected performance requirements. Typically found in pharmaceutical industry where hundreds of compounds are formulated and tested.	(D'Este et al., 2016; Dong et al., 2018; Kola, 2008; Kumar et al., 1996; Moenkemeyer et al., 2012)
5	Investment failure	A failure in the due diligence processes associated with the decision to start an innovation project.	(Gao et al., 2000)
6	Failure to adapt to changing technology	The failure to adapt to wider 'destructive gales' of technology change, e.g. Kodak, Nokia and Blockbuster.	(Gershon, 2013; Scaringella, 2017)
7	Management failure	Innovation failures are caused by bad management outside of the innovation project such as insufficient time/funding, or bankruptcy.	(Sabel et al., 2013; Scaringella, 2017)
8	Failure due to market and technology uncertainty	Non-specified failure attributed to the highly uncertain nature of technology development and market opportunities associated with innovation projects.	(D'Este et al., 2016; Jenson et al., 2016; Rhaiem and Amara, 2021)
NB	The purpose here is to examine "Innovation failure". The concept of 'learning from failure' is a separate stream of literature in its own right.		

the same became (almost by definition) a reason for failure. It is noteworthy that the review itself identified only a limited consensus on the factors contributing to project outcomes. We suggest that innovation phenomena are more complex than implied by a simplistic logic linking presence/absence of a factor to a success/failure outcome. Many of the recent empirical papers evaluating the effects of innovation failure define it in terms of project non-completion (D'Este et al., 2016, 2018; Hyll and Pippel, 2016), which is also, at the level of the project, non-success. However, success and failure are not necessarily simple opposites (Ika, 2009) and identifying the success factors does not reveal the causes of failure (Pellegrino and Savona, 2017).

Conceptualising innovation failure as "not innovation success" is understandable from the pragmatic perspective of a manager answering an academic researcher's interview question about a prior project. Such historical projects might, at that moment in time, be categorised as success or a failure. However, because a project's categorisation as an "innovation failure" might change over time we need a conceptualisation that accommodates such shifting perspectives. Godin and Vinck (2017) argue that the limited scholarly attention given to innovation failure is a manifestation of the *pro-innovation bias* (Rogers, 1962, p.142) that dominates the research literature. Their critique is that academic research focuses on the work of innovators, and this has resulted in a dominant representation of innovation as technological and 'good' for society. Their suggestions for alternative approaches side-lined by this dominant representation includes innovation failure (Godin and Vinck, 2017).

2.3. Learning from failure

It is widely established within management research that failure may be generatively framed as a learning process, and this perspective has been labelled "learning-by-doing" (Arrow, 1962). In their literature review on success and failure of innovation van der Panne et al. (2003) revise the term to "learning-by-failing" to emphasise the benefits to innovation of leveraging prior experience of failure. However, they do not examine the nature or meanings of failure itself. In a critique of the pro-success bias of innovation policy and research, Vinck (2017) attributes similar benefits accruing from experiences of innovation failure. Empirical research examining how firms seek to learn from the experience has encountered similar reasoning such as "studying failures is an opportunity or a precursor to future success" (Rhaiem and Amara, 2021, p.189), and "within some failures lie the seeds of subsequent project success" (Shepherd et al., 2009 p. 589). Indeed empirical studies have suggested that innovation failure is more likely to be found within firms conducting projects with a significant level of novelty (D'Este et al., 2016).

Other researchers have even explored whether the benefits of learning-by-failing might be realised by adopting a conscious strategy of making deliberate mistakes (Schoemaker and Gunther, 2006): a process akin to falsification in the philosophy of science (Popper, 1959). In seeking to account for empirical evidence demonstrating that the experience of failure leads to later improvements in percentage of turnover from new products, Leoncini (2016) argues that such failure acts as a spur to further innovative activity. He reasons that failure increases a firm's knowledge stock and leads to the questioning of existing routines.

Valuable though these varied insights are, the theoretical emphasis is on *learning* rather than the concept of innovation failure itself. Indeed, Vinck (2017) concludes his review of "Learning thanks to innovation failure" with the suggestion that "In innovation too the study of failure should be encouraged as it is likely to stimulate new modelling and theorization", (Vinck, 2017, p.235). Our paper responds to this suggestion and proposes a new conceptual framework of innovation failure itself.

3. Methodology

The methodology has been guided by the principles and best practices for systematic literature reviews of management research (Denyer and Tranfield, 2009; Tranfield et al., 2003; Rojon et al., 2021; Kunisch et al., 2023). Following these principles, a systematic review should be transparent, explanatory, inclusive and heuristic. This review is transparent in that we follow a rigorous methodology that is explained in this section. Of particular note is that we have followed a detailed process of thematic analysis in order to synthesise our selected papers.[1] In this we respond to the recent concerns of Rojon et al. (2021) that insufficient rigor has been applied to the synthesis methods in systematic literature reviews of management research. By means of our thematic analysis we aim to explain the meanings of innovation failure evident in the extant literature. Our selection of literature is inclusive of studies using both quantitative and qualitative data. The output of this review is heuristic

[1] Our final search results are predominantly journal articles, but also include 6 book chapters. Where we use the term 'papers' this is used as a short form of 'research papers or book chapters'.

in the sense of providing a guide to inform practitioners in their orientation towards, and management for, innovation failure.

Our methodology is presented below in three main stages: the search of papers related to innovation failure; the selection of papers based upon criteria of quality and relevance; and the synthesis of selected papers by means of thematic analysis.

3.1. Search strategy

The search process started with the development of search strings, designed to capture relevant papers. In this our previous reading of the innovation management literature had revealed that some discussions of innovation failure could be found in papers whose research subject was actually innovation success. That is, some papers address more than one of the topics indicated in Fig. 1. Therefore, both failure and success featured as key words in our search strings. The other key words sought to reflect concepts and major categories of activity associated with the commercialisation of innovations. The final list of search strings is as follows:

- "R&D failure" AND "R&D success"
- "Innovation failure" AND "Innovation success"
- "Research failure" AND "Research success"
- "Adoption failure" AND "Adoption success"
- "Technology failure" AND "Technology success"
- "Diffusion failure" AND "Diffusion success"

We applied the search strategy to the chosen bibliographic databases of: Web of Science, EBSCO, and Science Direct. Each author deployed the search strategy in one of the databases. Combining the results from all three searches generated a long list of 2477 papers. The selection of studies for the next phase was undertaken by subjecting each paper to a series of criteria (Table 2), with reasons for inclusion and exclusion being noted as per the PRISMA framework for systematic reviews (Moher et al., 2009), which has been applied to systematic reviews in the innovation domain (e.g. Stornelli et al., 2021).

3.2. Selection of research literature

Having removed duplicates from the long list, the selection of papers was conducted by all three authors. The process of selection proceeded through four stages of independent reading and discussion amongst all authors to agree the final list of papers for synthesis (Section 3.3). Table 2 provides a summary of the refinement through the four stages of selection, along with associated exclusion criteria. If, following discussion amongst co-authors, it was unclear whether a particular paper was relevant, then it was allowed to proceed to the next (more detailed) review stage. In the first stage of exclusions, all paper and publication titles were read to confirm they fell within the topic area of innovation studies. Many papers were excluded at this stage because they related to non-management topics (e.g., they were engineering design papers or reported the finding of original research in the natural sciences). The abstracts of the remaining 363 papers or book chapters were read in the second selection stage by each author and those discarded (Stage 2) that did not indicate findings or theories related to innovation failure; thereby leaving 104 articles. The third stage involved a reading of the full article to identify those that reported organisational-level studies of innovation, and which included conceptual or empirical material related to innovation failure. The exclusion criteria for the second and third stages was the same, because many papers could not be excluded with confidence on the basis of a reading of the abstract alone (i.e. Stage 2).

The total number of papers after the third selection stage was 42. A reading of the full text made evident the limitations of the initial bibliographic search strings as article reference lists included potentially-relevant papers not within our results. This limitation of initial searches has long been recognised in SLRs in management studies (e.g. Greenhalgh et al., 2004; Pittaway et al., 2004). It has become common practice (Wohlin, 2014) to follow a "snowballing" strategy of examining the reference lists of selected articles to identify additional relevant studies. Therefore, a final phase of such 'snowballing' was included, in which we examined reference lists of the 42 articles selected after stage 3 in order to identify other possible relevant papers. Any papers suggested by this method were then reviewed by repeating selection stages 2 and 3 to create a final total of 69 papers to be included in the thematic analysis stage. A summary of this selection method and associated exclusion criteria is presented in Table 2.

Table 2
Summary of criteria for selection of studies for review.

Stage	Method	Reasons for exclusion	Total
0	Bibliographic searches	Original "long list" of papers	2477
1	Reading of title of the paper and journal	Does the paper fall within the broad topic of innovation studies? Exclusions: • Not a management or organisational studies discipline • Focus of paper is on engineering or technical design • Not a full paper or Book chapter • Not in English • Duplicates	363
2	Reading of Abstract	Does the paper report/discuss firm-level innovation failure? Exclusions: • Concerned with unrelated innovation management topic • Failure of a secondary implementation of information system • Failure at innovation diffusion stage • Policy document • Failure in a national innovation system • Concerned with impact of failure (e.g., on share price) • Management education papers	104
3	Reading of Full Paper	Do the papers provide detailed findings or theories related to innovation failure at an organisational-level? Is the paper a literature review of this topic? Exclusions: • Same as Filter 2	42
4	Snowballing	Reviewing reference lists of the 42 papers after stage 3, then evaluating their relevance using the same criteria as stage 2 & 3.	69

3.3. Synthesis of selected papers

The synthesis of data, concepts and arguments related to innovation failure was achieved by means of an inductive thematic analysis following the Gioia method (Gioia et al., 2013).

Step 1: Capturing statements related to innovation failure and creating first order concepts. The selected papers were divided equally amongst the three authors who then conducted this stage independently and generated their own first-order concepts, before consolidating the analysis. The allocated papers were read, looking for any text that defines, discusses, conceptualises, or reports empirical results related to "innovation failure". Open coding (cf. Locke, 2000) involved extracting such text direct from the paper to produce a long list of discrete statements related to innovation failure. The majority of such statements were found in the literature, research findings and discussion sections of the papers. Any repetition of the statements in Introduction, Conclusion or Abstract sections was not recorded. In other words, no significance was attributed to multiple mentions of the same point: this being treated as a stylistic feature of the paper authors' writing.

Those statements expressing similar ideas were then clustered and

summarised in a short sentence to articulate a "first-order concept". At this point the authors shared their list of statements clustered by first-order concepts. In total a long list of 57 first-order concepts was produced. During multiple meetings, the authors discussed these 57 provisional categories in turn, familiarising themselves with the statements extracted from the papers, and noting similarities in other first-order concepts produced by their fellow authors.

Step 2: Integrating first-order concepts and creating theoretical categories. The three authors completed the consolidation of the 57 first-order concepts together in meetings. Whilst the terminology of the first-order concepts remained close to the words used in the texts of selected papers, the consolidation of categories became more theoretical and abstract. This is in keeping with the analytical shift from open to axial coding (Locke, 2000). This more abstract language reflected the management and organisational theories evident in the framing of the selected papers (e.g. theories of learning, process, capabilities etc.). In discussion together the authors iterated between the ideas on innovation failure in the original papers and the emerging theoretical constructs to generate a shorter list of "second-order themes". The choice of labels for these themes again involved iterating between the particular language of the innovation failure papers and theory.

Step 3: Delimiting theory by aggregating theoretical categories. The next phase of analysis involved working with second order themes to construct the meanings of innovation failure. Different ways of combining the themes (into "Aggregate Dimensions") were tried and tested in discussions amongst the authors and with research colleagues. For example, some categories seemed to relate to the everyday processes of innovation management (e.g., "risk management"), but others were more strategic in nature (e.g., "portfolio management"). We discussed alternative conceptual frameworks that described how these themes related to one another and to the organisational theories deployed by the authors of the selected papers. The types of conceptual frameworks we explored included: causal models, hierarchical frameworks, linear process model connecting all three aggregate dimensions; as well as the discrete processual models. For each possible framework, we re-examined the extracted text on innovation failure from the selected papers with our emergent theoretical understanding (Locke, 2000). A summary of the final data structure (cf. Gioia et al., 2013) for this analytical process is shown in in Fig. 2. The references contributing to each theme are shown in an expanded table in the appendix, Table 4.

4. Findings

This section reports the findings of our synthesis of the literature selected during the systematic review. Our aim was not to identify failure causes or antecedents, but to understand the meanings of innovation failure within this research literature. Our systematic review of the literature provided evidence for questioning the taken-for-granted assumptions about innovation failure (Section 2). We problematise debates surrounding factors that lead to innovation success or failure by arguing that the literature shows "failure" is often a provisional label. The theoretical implication is that the concept of innovation failure needs to attend to this temporal nature. We suggest a consequence of the focus of the 'Learning from Failure' literature is that it leaves under-examined the nature and meaning of failure itself. The theoretical implication is that we need to clarify the nature of such events in order to make a distinction between the learning before and after such events. We construct a new conceptualisation of innovation failure that addresses these problems and their theoretical implications, by means of a theory-building inductive synthesis of our selected papers. The following sections are organised in relation to the underlying patterns suggested by our analysis (Fig. 2). Thus, findings related to each of the three *aggregate dimensions* are structured by sub-sections for each of the *second-order themes* that constitute them.

4.1. Innovation failure as experimentation

The aggregate dimension of 'failure-as-experimentation' reflects the practice of regularly testing new ideas and our review confirms that the practice is widespread in the literature on innovation failure. This in itself is not an unexpected finding. The practice of prototyping is founded upon the principle of experimenting rapidly and frequently (Thomke and Reinertsen, 2012) and Toyota's product development system includes the detailed analysis of hundreds of alternatives, most of which are abandoned (Liker and Morgan, 2006). Our thematic synthesis of the literature suggested that *Experimentation* could be used to categorise a variety of innovation activities in addition to those technical experiments conducted by scientists and engineers. Thus, we interpret the equivocality of the literature regarding the influence of managers on failure as reflecting the experimental nature of the innovation management task. Experimentation is thus an important organisational learning mechanism and is occurring all the time during the innovation process, and not only after failures significant enough to trigger project termination.

4.1.1. Innovation process management

Management of the innovation process is central in many discussions of innovation failure, but on the question of whether failures can be attributed to poor management the literature seems equivocal. Many discussions of innovation identify shortcomings in innovation management, such as "deviation from rules, poorly planned or badly conducted product development activities, or avoidable repetition of prior mistakes" (D'Este et al., 2016, p.288). Similarly, failure is presented as a misallocation of resources (Marzocchi and Ramlogan, 2019), or as ineffective implementation of otherwise sound innovations (Robertson et al., 2008). In one study Sabel et al. (2013) attributed 64 % of innovation failures (VC funded startups) to bad management; a finding that prompted them to argue that the "majority of innovation failures are caused by management problems not by lack of time or technology" (2013, p.369). However, other research has noted the influence of the wider operational environment of the firm on innovation management. Thus, Spiller and Teubal suggest that failure is less a matter of incompetent management than "inappropriate firm behaviour, the workings of uncertainty, or by a combination of the two" (Spiller and Teubal, 1977, p.257). Other researchers have drawn attention that a lack of funds (rather than poor management) can itself be a cause of project failure (Harrison, 2003).

4.1.2. Managing novelty

There is an inherent experimental quality to the pursuit of novelty which necessarily introduces uncertainty into the innovation process and increases the risk of failure (D'Este et al., 2016). There is a good deal of empirical support for the claim that new-to-the-market innovation has a higher likelihood of failure (e.g. Leoncini, 2016). Further, a small increase in the number of exploratory projects brings a large increase in project failure rates (D'Este et al., 2018). This increased failure rate of novel projects is in part due to technology risk and capability gaps, but novelty also introduces market risk (Potts, 2010). Further, Potts (2010) also found that the failure to notice novelty during innovation projects leads to an underestimation of its impact. The upside of pursuing novel and uncertain innovations is that all research produces new knowledge (Harrison, 2003), but failure itself is a distinct and important source of new knowledge that is often overlooked (Leoncini, 2016).

4.1.3. Risk management

The risk management group of papers recognises that in the management of innovation projects, one of the things being attended to is risk. The (false) expectation that all projects will succeed given enough learning has been labelled the efficient innovation hypothesis: "all agents know what to do next… Mistakes will not occur, regret will not be experienced, and expected utility will be an unbiased estimate of actual

Fig. 2. Innovation failure thematic data structure.

utility" (Potts, 2010, p.135). In the risk management group, this optimistic perspective is countered by an analytic one, which seeks to balance expectations of return against the risks of failure (D'Este et al., 2016) based on the recognition that some failure will occur (Potts, 2009). From a process perspective, innovation failure can be seen as a risk management problem and research has identified specific types of risk which are most relevant to innovation failure. Yang et al. (2000) suggest that investment risks (which they related to risk techniques and market risk) are principal causes of innovation failure. When the risk perspective is applied to formal R&D processes, Shin et al. (2018) observe that different types of risk and failure are evident in each stage of a stage-gate process. Studies of risk management have also found variability in risk propensity (Moenkemeyer et al., 2012) as managers take calculated actions whose outcomes are uncertain, and whose consequences may entail significant project downsides (Mohnen et al., 2008). A high risk-propensity means a high willingness to take on risk, or rather a willingness to take on projects with high risk of failure.

4.1.4. Innovation capabilities

Organisational capabilities have been defined as "collectively held and action-oriented knowledge that enables firms to get things done" (Pandza and Thorpe, 2009, S118). In the context of innovation failure this action-orientation revolved around the testing of ideas, with the collective knowledge originating both within and outside of the firm. External collaborators are often used to provide technology capability, including new engineering effort through contracting or partnerships, and through existing intellectual property such as patents (Radas and Bozic, 2012; Yap and Souder, 1994). Innovation capability directly influences innovation performance (Sawng et al., 2019), but still capability is not given adequate attention: "People and firms systematically under-invest in developing innovation competences" (Potts, 2010, p.142). Here, not only is the initial investment in capability inadequate but then the complexity (and so effort) required is also underestimated. This results in under-estimates of resources required.

4.1.5. Hypothesis-testing experimentation

Hypothesis testing is a central part of the scientific method, and is widely applied in science and engineering R&D efforts to advance knowledge and learning in a systematic way. Experimentation more broadly is a necessary and valuable part of the innovation process, and one which generates informative failure (and success). Failures in R&D are often described as an inevitable part of the (hypothesis-testing) scientific method and necessary for the achievement of success (Harrison, 2003; Magazzini et al., 2012; Morais-Storz et al., 2020). Such failure provides crucial learning (Potts, 2010), and is unavoidable (D'Este et al., 2018). Indeed some knowledge produced by R&D remains tacit and could only be acquired by testing (Harrison, 2003). Conducting more radical experiments brings a greater likelihood of failure but may lead to more significant learning opportunities. Incremental innovations that pursue efficiency by the elimination of waste might also eliminate the 'good waste', "the necessary but unknown costs of experimentation" (Potts, 2009, p.38). Viewing failure as a necessary outcome of hypothesis-testing might generate opportunities that might otherwise go unnoticed (Khanna et al., 2016; Leoncini, 2016).

4.2. Innovation failure as judgement

The aggregate dimension of 'failure-as-judgement' expresses a conscious, purposive action to label an innovation (and the particulars of its development) as a failure. Such naming of an innovation as a 'failure' is a way of framing it at a particular moment in time. To view innovation failures as *frames* is to see them as 'cultural resources' that managers deploy in order to suggest new action possibilities (Rindova et al., 2011; Weber and Dacin, 2011). Thus, our second dimension identifies the 'declaration of failure' as a strategic act that is used by managers as a means of initiating a distinctly new direction in the innovation process. Whilst failing is always happening during the experimental activities of innovation (cf. Section 4.1), a conscious 'declaration of failure' gives everyone permission for a reset in innovation activities. Such declarations represent innovation narratives (Bartel and Garud, 2009) of 'what went wrong' structured in such a way to suggest new 'strategies of action'. These narratives may explain failure as the wise reallocation of resource to more promising projects in the portfolio. Significantly they also position the failure as a temporary state of affairs, with the potential for the innovation project to be revived.

4.2.1. Technology life cycles

An important characteristic of the business environment is ever-changing technology (Chung et al., 2017). Innovation that includes new technology is therefore part of this changing environment and occurs within an evolving technology life cycle. Technology selection is part of the decision process in developing new innovations, and it is argued that "failures could be minimized by improving the idea selection process in order to reduce the risk of betting on the wrong technology" (Rhaiem and Amara, 2021, p190). Technology development is therefore an important endogenous factor, beyond the firm. Some technologies follow well understood patterns such as those of mass-produced consumer technology products. Other technologies such as electricity generation from wind power more closely resemble the life cycle of complex products and systems. In such cases the overarching design hierarchy can govern the period in which certain components become the focus of the inventive activity. These patterns, which are reflected in the subsequent patenting activities, can influence entire industries. Technology life cycles differ considerably and affect decisions within firms to do with the time and cost of developing the technology, the timeline of recovering cost, and modes of making the technology yield a profit proportionate to the costs and risks involved.

4.2.2. Perceptions of failure

The negative perceptions of failure are extremely important to innovation, since they may lead to destructive and irrational practices. These strong negative perceptions of failure are caused in part by the psychology of loss aversion (Potts, 2009). There is a potential stigma of being associated with an innovation that has been labelled as a failure (e.g. Potts, 2010; Leoncini, 2016). The stigma may also be attached to the project itself and this reduces the likelihood of reusing valuable learning developed from a 'failed' innovation in future projects (Obermöller, 2013). Innovation project terminations have also been found to have a detrimental effect on project members (Välikangas et al., 2009; Shepherd et al., 2009), in part because of the negative stigma that failure brings.

The impacts of perceptions of failure play out differently over time. The very perception of innovation obstacles reduces the likelihood of engaging in innovation in the first place (Pellegrino and Savona, 2017). Failure on a small scale (at the project level, and ideally early) can be thought of as an "active element that firms experience in their quest for innovation success" (Marzocchi and Ramlogan, 2019, p.1464). The timing associated with identifying a project as failed is important, as an apparently failing project "may eventually succeed as conditions outside the innovator's control change (such as emergence of complementary technologies or maturing of user attitudes (Välikangas et al., 2009, p.231)". There is evidence to suggest that a perception of failure for one individual or stakeholder group is not necessarily a failure for another, and indeed innovation can be labelled as both success and failure at the same time (Dudau et al., 2018; Edmondson, 2011).

4.2.3. Portfolio management

Firms operate portfolios in the expectation that occasional successes will compensate for smaller and more frequent losses (Scherer, 2015; Wezel and van Witteloostuijn, 2006). Portfolio management features a great deal in the innovation failure literature (Kralisch et al., 2016; Kumar et al., 1996; Wang et al., 2010). Firms operating in contexts of

high uncertainty have been found to adopt a probability-based approach that conceptualises innovation projects decision-making as judgements within a portfolio, most of whose projects will fail (Dumay et al., 2013). For example, pharmaceutical companies engaged in drug discovery are very likely to consider a project-portfolio management strategy (Osakwe, 2016a) that evaluates potential groups of drug compounds rather than single projects. In this scientific setting the innovation funnel model with a decreasing number of projects over time will be a reasonable reflection of how their portfolios actually operate (Ringen and Welo, 2013).

Innovation strategy advice will often recommend that a portfolio balance of short-term versus long-term opportunities and incremental versus breakthrough innovations (Loewe and Dominiquini, 2006). Firms with larger portfolios of products, suppliers and stakeholders are thought to be more resilient to failure (Leoncini, 2016), and this is the key rationale behind a portfolio approach. A further benefit of operating a portfolio is that the ability to innovate is improved by "a portfolio of inter-related activities" (Marzocchi and Ramlogan, 2019, p.1463). Indeed when innovation activity is considered as learning, R&D projects might be carried out "where the intent is to learn about competitors' technologies or market potential knowing that some of those will be eventually abandoned" (Marzocchi and Ramlogan, 2019). Therefore, in contrast to the negative perceptions of failure that might exist at an individual level (cf. Section 4.2.2), these strategic practices make it acceptable to declare an individual project as a failure for the good health of the wider portfolio.

4.2.4. External collaboration

Whilst collaboration with external partners is associated with a higher propensity for innovation, it is also associated with a higher risk of failure (D'Este et al., 2016; Guzzini et al., 2018). A primary motivation to collaborate with external companies is to gain "access to the leading technology from the supply chain" (Ren et al., 2016, p.48). Partners can also add innovation capability, which reduces knowledge risk (Dumay et al., 2013).

Collaboration exists in a range of patterns, and each model of collaboration has a different set of relationships with innovation failure. One analysis of the UK innovation survey data examined firm responses to failure and found that they vary depending on the innovation strategy. Innovation failure had a small negative effect on future innovation where the innovation was based on internal knowledge sources (Marzocchi and Ramlogan, 2019), but there was no effect where the innovation was based on cooperation. An analysis of the German community innovation survey data showed that different partners have different effects (Hyll and Pippel, 2016). When all innovation types are considered together, cooperation with suppliers was the only one found to be highly significant (Hyll and Pippel, 2016), where more collaboration also corresponded with more failure. Where product and process innovation are considered separately, cooperation with universities reduced product innovation failure. Cooperation with suppliers and competitors both increased process innovation failure, and cooperation with research institutes reduced process innovation failure (Hyll and Pippel, 2016). Whilst these authors propose a number of explanatory mechanisms, the challenges of managing collaborations, rather than the technical development of the innovation, is the main source of failure. However, such collaborations may be a sign of the partners' pursuit of radical innovations (D'Este et al., 2016) which implies failure is a risk that is due to novelty rather than a failure of collaborative management.

Overall, the failure of a collaboration is a strategic event that enables a fundamental reset in the innovation project. The focal firm, lacking the innovation capability of the partner cannot quickly 'go it alone'. Therefore, we position the failure of innovation collaborations as providing strategic managers with the justification to pause and rethink the future course of the innovation.

4.3. Innovation failure as event

The aggregate dimension 'failure-as-event' concerns instances when an unexpected shock or crisis occurs that means an innovation is unequivocally deemed a failure. In contrast to proactive strategic resets that proceed failure-as-judgement, it is the shock or crisis itself that necessitates an innovation management response that is shaped by the circumstances of the event. The theoretical standpoint for this aggregate dimension is rooted in the organisational change literature addressing the issue of 'recovery from failure'. Typically this follows major disasters (such as the now classic cases of Blockbuster and Kodak as analysed by Gershon, 2013) where the emphasis is on "the establishment of an effective problem-solving activity capable of generating much needed organisational changes to survive the crisis" (Leoncini, 2016, p.377). This dimension is constituted of the second order themes of 'failure avoidance' and 'learning from failure'. The former expresses a rational but ultimately self-destructive pursuit in an uncertain environment. We argue that the literature categorised as 'learning from failure' may be best positioned in this aggregate dimension because it is invariably concerned with unequivocal failure. Within this dimension research explicates the behavioural response to an unequivocal failure event, either realised or in prospect.

4.3.1. Learning from failure

Learning from failure is the practice of focused failure analysis, usually with the intention of improved future performance. It is also a complex topic that needs careful management to prevent blame seeking and rise above superficial lessons (Edmondson, 2011).

There is a significant thread of research on the theme of 'learning from failure', which has itself been the subject of literature reviews (Cannon and Edmondson, 2005; Rhaiem and Amara, 2021). Rhaiem and Amara (2021) noted a variety of ways of conceptualising learning from innovation failure, both as a personal belief and as a corrective action that is found to have positive effects. They develop a conceptual framework discussing the influence of thirteen variables on 'learning from innovation failure', which then itself influences both strategy and organisational outputs. The emphasis on learning is positioned as the way to transform failure into a valuable experience (Harrison, 2003; Khanna et al., 2016), and provide a spur to new innovative behaviours (Marzocchi and Ramlogan, 2019). Empirical evidence from the community innovation survey shows that failure "has a positive impact on performance in term of [sic] percentage of turnover from new to the market innovative products" (Leoncini, 2016, p.376). Failure and learning are intertwined and learning occurs through the innovation process and not only after failure events (D'Este et al., 2016; Madsen and Desai, 2010).

Innovation failure has been found to have a negative impact on project personnel (Shepherd and Kuratko, 2009; Cannon and Edmondson, 2001, 2005), and the opportunity to learn can be read as providing emotional comfort (Välikangas et al., 2009). This in part explains why one firm's innovation success was attributed in part to "allowing a 'safe failure space' for the team to learn from failures and eventually find the breakthrough" (Luqmani et al., 2017, p.103). Learning from failure may indeed have a different objective, not to stop failure but rather to keep innovating in the face of failure: "innovators can learn more from their project failures and remain committed to future innovative endeavours" (Shepherd and Kuratko, 2009, p.451).

4.3.2. Failure avoidance

Innovation failure is often presented as an undesirable outcome to be avoided. This may be in order to prevent the loss of the project investment, the disappointment and grief experienced by colleagues (Shepherd et al., 2009; Shepherd and Kuratko, 2009), or because of the political damage caused by failure (Leoncini, 2016). However, failure avoidance has several negative consequences. As particular drivers of failure avoidance, loss aversion (Potts, 2010) and escalation of

commitment (Yang et al., 2020) conspire to prevent NPD projects from being terminated at gates (Yang et al., 2020). This means that a great many more projects are completed where they should instead have been abandoned (Barnett and Freeman, 2001). Post-launch failure is by far the most expensive, and this becomes more likely because of failure avoidance. This tendency dramatically multiplies the extent of project losses, which are more expensive after launch than during an earlier stage in the project (Banyte and Salickaite, 2008).

Failure avoidance also results in a smaller number of projects being started (Madsen and Desai, 2010). However, as the degree of novelty in the project portfolio is reduced, the potential benefits from innovation are also likely to be diminished. Such a position is often associated with being overly cautious. Uncertainty can be thought of as that which is not easily measurable in terms of probabilities, where we may even be unsure of what possibilities exist. This is frequently the case in systems composed of many interacting elements where all of the actors operate under conditions of uncertainty, such as that for electric vehicles. Disruptive innovations and the consequential destruction of firms provide clear evidence of why firms need to be vigilant for dramatic shifts in their industry. Thus, adopting an overly cautious position also has its dangers and risks and may lead to catastrophe for the firm such as occurred with Nokia and Kodak (Leoncini, 2016).

5. Discussion

Our systematic review of the literature has confirmed our initial reading that the concept of 'innovation failure' does not have a clear theoretical underpinning; significantly it is frequently not defined at all and has many interpretations. It is viewed as a single concept having different types (Rhaiem and Amara, 2021); as we illustrate in Table 1. As such the concept would seem to have limited value beyond the straightforward notion that a project has been terminated for reasons that make sense given the immediate and particular context of an organisation. In arguing for more generalised meanings of 'innovation failure' our paper addresses the calls for new theorisation of innovation failure (Scaringella, 2017, p.1) (Vinck, 2017, p.235). The paucity of such research is somewhat puzzling, given the policy relevance of identifying and reducing the barriers to the firm's decision to spend on innovation activity. It is known that innovation is an inherently uncertain endeavour. At any moment an innovation project might be judged to be a success or failure; and as our review has shown opinions may differ at any moment on this matter. As a consequence, it does not follow that failure is "not success" (cf. Section 2.2). This becomes more apparent when a wider temporal perspective is adopted: neither failure nor success can be absolute attributes. If failure at one moment in time can become success at another then we need a conceptualisation of failure that is not fixed; one that allows for the various ways in which failure contributes to innovation management.

In order to make explicit varied generative perspectives on innovation failure our systematic review contributes a reconceptualisation of the concept of innovation failure along three dimensions (see Table 3): *failure-as-experimentation; –judgement and -event*. Our triangular conceptual framework in Fig. 3 is a helpful visualisation of the three dimensions of innovation failure. We not only identify three distinct categories of failure, but we also show how each category generates a different type of actionable knowledge: the "next iteration" for the dimension of experimentation refers to the continual process of hypothesis-testing and problem solving; a proactive "strategic reset" for the dimension of judgement recognising the agency of innovation managers in initiating completely new innovation approaches, or to redirect funding to other projects; and actions for "organisational recovery" following an unequivocal failure event that makes untenable the continuation of the innovation is untenable in its previous form.

With this framework we contribute a processual conceptualisation of the literature on innovation failure. In Section 2.2 we noted that much of the literature positions 'failure' in contrast to 'success'. This orientation leads to framing research on innovation failure in terms of barriers to be overcome (e.g. D'Este et al., 2016), failure at different stages of innovation (e.g. Marzocchi and Ramlogan, 2019) and even "a problem in a firm's economic activity" (Leoncini, 2016, p.376). Such framings imply that failure is something to be avoided. In contrast, our processual conceptualisation emphasises that failure is an unavoidable and necessary feature of innovation (F1, failure-as-experimentation).

Our analysis reveals that 'failure' is often a provisional label, and that it is important to adopt temporal perspectives when theorising innovation failure. This concept is treated in many empirical studies as some

Table 3
Reconceptualisation of innovation failure.

	Aggregate Dimensions	Characteristics	Key illustrative and supporting literature
F1	Failure as Experimentation	The processual mechanism of "failure as experimentation" is an on-going part of the innovation process. It is not limited to technical or design developments of a product but is also evident in project management decisions where product hypothesis-testing meets practical problem solving. Innovation failure through "Experimentation" unfolds continuously during an innovation project and is viewed as necessary for realisation of novelty.	Marzocchi and Ramlogan, 2019; Välikangas et al., 2009; Thomke and Reinertsen, 2012
F2	Failure as Judgement	The processual mechanism of "failure as judgement" recognises that innovation failure is often a matter of individual perspective, where for different stakeholders the same innovation is both a success and a failure at the same time. Failure is thus a matter of judgement and thereby equivocal. Innovation failure through "Judgement" unfolds through the creation of a narrative of failure on the part of innovation project leaders. The aim of such narratives is to enable completely new innovation approaches, or to redirect funding to other projects.	Weber and Dacin, 2011; Rindova et al., 2011; Bartel and Garud, 2009; Dudau et al., 2018
F3	Failure as Event	The processual mechanism of "failure as event" follows a sequence of events (often external to the innovation project) that create an unequivocal shock or crisis that makes the continuation of the innovation project untenable. Innovation failure through "event" unfolds through behavioural responses that emphasise learning from the failure event in order to support organisational recovery. In being shaped by the immediate circumstances of the event, such learning is different from a more generic 'learning from previous failures' that informs innovation management in the absence of shocks and crises.	Gershon, 2013; Leoncini, 2016; Bergek et al., 2008; Klein Woolthuis et al., 2005; van Mierlo et al., 2010;

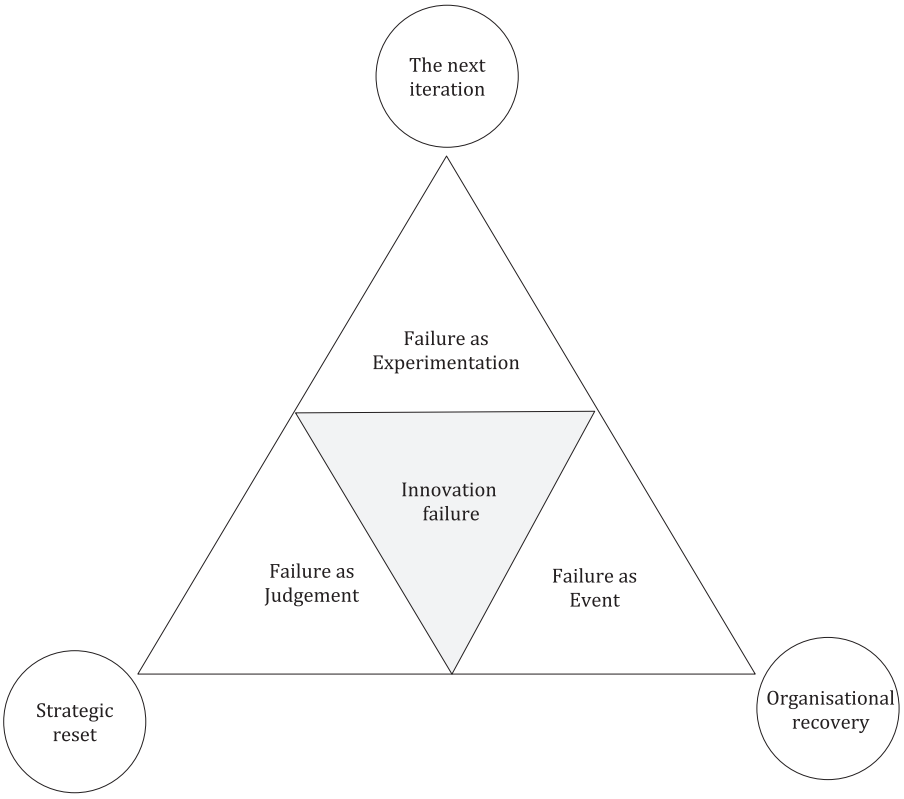

Fig. 3. Conceptual Framework for the three dimensions of innovation failure.

absolute state of affairs when, if a longer temporal perspective is taken, it is often provisional. A shelved innovation project might be revived or transformed. All innovations might in time be labelled 'failures' inasmuch as they are replaced by newer better products or services. Many innovation challenges that are unmet today will eventually succeed with sufficient passage of time. That is, most unsolved technical and commercial challenges will eventually be solved. Similarly successful innovation projects can become failures as new challenges present themselves with the passage of time. In explicating the processual mechanisms of failure our conceptual framework allows us to address the temporalities of innovation failure.

As we observed in Section 2.3, the theoretical emphasis within the "learning from failure" literature is on organisational learning. We also argued that learning is inherent to all innovation and innovation failure invariably creates new knowledge that it might leverage at any time. Our concern in this paper is examining the concept of failure itself and the ways it contributes to our understanding of innovation. In failure-as-event we draw attention to major shocks and crises that necessitate learning that often extends beyond the innovation itself. Innovation management following an unequivocal failure event is shaped by the circumstances surrounding that event. For example, there may be a need to mitigate adverse impacts of the innovation, or innovation goals may be changed in include organisational recovery.

5.1. Limitations

This review has provided a systematic synthesis of the research on innovation failure. Specifically, this review examines the concept of innovation failure at the level of the firm and from an innovation management perspective. It would be possible to explore the topic of innovation failure at a different level of analysis, to consider innovation regions (Filippopoulos and Fotopoulos, 2022) or clusters (Doehne and Rost, 2021), ecosystems (Andrews et al., 2022), policy (Kivimaa and Rogge, 2022), or history (Taalbi, 2017), or by adopting a wider perspective to consider either the adoption of innovations by society (Rogers, 2003) or the study of technological transitions (Geels, 2002, 2022). A bibliometric study (e.g. Souzanchi Kashani et al., 2022) or a computational literature review (Antons et al., 2021) might also allow a much wider synthesis across multiple domains, showing progression over time and interrelations between these domains.

Despite its focus on innovation management, this review had a broader scope than previous overviews of innovation failure (Rhaiem and Amara, 2021; van der Panne et al., 2003). The focus on scientific literature was chosen to safeguard the quality of the information, and whilst being common practice in innovation and management studies this focus is also a notable limitation (Rojon et al., 2021). Useful studies may also appear as grey literature, such as reports, working papers, government documents, white papers, and evaluations (see Adams et al., 2017 for detailed guidance of how to incorporate grey literature into systematic reviews). There may also be relevant publications in languages other than English.

5.2. Research agenda and implications for policy and practice

Further research is required to examine the relationship between the innovation process of learning from experimentation (which includes failure), learning from shelved projects (judgement) and learning from an organisational crises or catastrophic failure. This study of different organisational learning mechanisms should help to clarify the lines of debate with these separate failure constructs, which have become entangled.

In addition to organisational learning, knowledge creation (Nonaka, 1991) offers a potential avenue for studying the effects of iterative learning and feedback loops (Akbar et al., 2018), and in particular there is scope to expand beyond the focus of successful projects or award-winners (e.g. Akbar and Tzokas, 2013) and to evaluate the full range of projects in existing portfolios. This would provide the opportunity to study the judgement dimension in practice, including the strategies and

tactics employed by managers when making decisions that represent a personal setback (Moenkemeyer et al., 2012) and which cause grief (Shepherd et al., 2009; Shepherd and Kuratko, 2009). Longitudinal studies might also examine the long-term value of cancelled projects either in terms of learning, intellectual capital, or as a valuable, rare, inimitable non-substitutable firm resource which contributes to competitive advantage (Barney, 1991).

At the policy level, this study could inform research determining how Research Grant Awarding bodies such as the UK's UKRI and the EU's ERC should address the generative possibilities of failure for a fuller understanding of innovation. The paradox of innovation failure is that there can be no innovation, at least in the long term, without failure. A move away from failure is a move towards lower risk projects with more certain returns. For research funding agencies this means allocating funding to projects which are less defined and more uncertain. Our analysis shows that many organisations explicitly try to avoid failure, that there is a particularly strong tendency for this in the public sector, and that failure avoidance causes an innovation deficit (Potts, 2009). Indeed, some prominent scholars argue that the failure avoidance embedded in the current scientific funding model "tends to invite either exaggeration or boringly predictable projects" (Ioannidis 2011, p.529). Failure avoidance on the part of the funding agency might prevent ambitious research. This prediction is not borne out in all cases, and a recent analysis of ERC research projects showed that 80 % made either a scientific breakthrough or a major scientific advance, and that only 2 % made no appreciable contribution (European Research Council, 2020). This extremely high success rate is in direct contrast to the innovation literature, which predicts that "few innovations will succeed and most will fail" (Dumay et al., 2013, p.618). The differences between the scientific endeavour and innovation, and the conflicting predictions about the outcome of failure avoidance, warrant further academic study and new policy mechanisms which embrace failure.

Finally, further research is required to test our claim that innovation success factors co-exist with and are indistinguishable from innovation failure factors. Our claim mirrors the recent research findings which show that the most innovative firms also have high innovation failure rates (D'Este et al., 2016), and so those factors which cause innovation success also cause innovation failure. Seeking success is not the same as avoiding failure, but this is not how failure is currently treated as an empirical phenomenon and the relationships between success, failure and their causes need to be re-examined.

CRediT authorship contribution statement

David Baxter: Conceptualization, methodology, formal analysis, writing – original draft preparation, writing – review and editing, visualization.

Paul Trott: Conceptualization, methodology, formal analysis, writing – original draft preparation, writing – review and editing, visualization.

Paul Ellwood: Conceptualization, methodology, formal analysis, writing – original draft preparation, writing – review and editing, visualization.

Declaration of competing interest

We have no conflict of interest to declare.

Data availability

No data was used for the research described in the article.

Appendix A

Table 4
Innovation failure thematic data structure, with references.

First-order concepts (indicative listing)	Second order Themes	References	Aggregate Dimensions
• Projects can fail for non-technical reasons (management, funding). • 'under-funding' of projects is itself a cause of failure	Innovation Process Management	Brockhoff and Chakrabarti, 1988; D'Este et al., 2016; D'Este et al., 2018; García-Vega and López, 2010; Gershon, 2014; Green et al., 2003; Kato-Lin et al., 2016; Harrison, 2003; Heidenreich and Kraemer, 2016; Kola, 2008; Kumar et al., 1996; Marzocchi and Ramlogan, 2019; Moenkemeyer et al., 2012; Osakwe, 2016b; Pandya and Dholakia, 2005; Robertson et al., 2008; Sabel et al., 2013; Scaringella, 2017; Spiller and Teubal, 1977; Svidronova et al., 2016; Xiong et al., 2020	Failure as Experimentation
• Exploratory R&D exposes the firm to both increased risk of failure and discovery of new knowledge. • Innovations associated with greater novelty are more prone to failure.	Managing Novelty	D'Este et al., 2016; D'Este et al., 2018; Harrison, 2003; Heidenreich and Kraemer, 2016; Leoncini, 2016; Pandya and Dholakia, 2005; Potts, 2010	
• The conception/search phase is associated with the benefits and failure risks of exploratory R&D. • The cause of a failure is hard to identify.	Risk Management	D'Este et al., 2016; D'Este et al., 2018; Gao et al., 2000; Gershon, 2014; Moenkemeyer et al., 2012; Mohnen et al., 2008; Potts, 2009; Potts, 2010; Shin et al., 2018; Townsend, 2010	
• Organisational capabilities for innovation are both built (in part) on failures and can reduce the likelihood of failure. • Employee competencies allows new emerging problems to be addressed.	Innovation capabilities	Potts, 2010; Radas and Bozic, 2012; Sawng et al., 2019; Yap and Souder, 1994	
• Well-informed Experimentation generates informative failure (and success). • Failure is unavoidable.	Hypothesis-testing Experimentation	Cannon and Edmondson, 2005; D'Este et al., 2018; Harrison, 2003; Khanna et al., 2016; Kola, 2008; Magazzini et al., 2012; Marzocchi and Ramlogan, 2019; Morais-Storz et al., 2020; Potts, 2010; Thomke and Reinertsen, 2012; Välikangas et al., 2009	
• Technology change is a continuous and important feature of the environment • Technology eco-systems exist at Industry level	Technology life cycles	Chung et al., 2017; Gershon, 2014; Rhaiem and Amara, 2021; Scaringella, 2017	Failure as Judgement
• Innovation failure has negative connotations. • We don't like noticing, pointing out, or learning from failure	Perceptions of failure	Edmondson, 2011; Morais-Storz et al., 2020; Harrison, 2003; Madsen and Desai, 2010; Mohnen et al., 2008; Dudau et al., 2018; Obermöller, 2013; Pellegrino and Savona, 2017; Potts, 2009; Potts, 2010; Shepherd et al., 2009	

(continued on next page)

Table 4 (*continued*)

First-order concepts (indicative listing)	Second order Themes	References	Aggregate Dimensions
• Portfolio thinking is economically rational, but is not behaviourally natural • An innovation deficit exists due to the conflict between the dynamic efficiency of experimentation and portfolio thinking and the behavioural / political aversion to (experimentation) failure.	Portfolio management	Potts, 2010; Kralisch et al., 2016; Loewe and Dominiquini, 2006; Marzocchi and Ramlogan, 2019; Osakwe, 2016a; Kumar et al., 1996; Ringen and Welo, 2013; Scherer, 2015; Spiller and Teubal, 1977; Wang et al., 2010; Wezel and van Witteloostuijn, 2006	
• The extra knowledge/capabilities of innovation collaborators may reduce the likelihood of technical failures. • The management of collaborations is difficult and may introduce a managerial source of failure.	External Collaboration	D'Este et al., 2016; Dumay et al., 2013; Guzzini et al., 2018; Hyll and Pippel, 2016; Lhuillery and Pfister, 2009; Marzocchi and Ramlogan, 2019; Ren et al., 2016	
• Failure can be a point of departure for personal and organisational learning processes. • The occurrence of failure may prompt the identification of new or neglected opportunities.	Learning from Failure	Chai et al., 2021; D'Este et al., 2016; D'Este et al., 2018; Dörfler and Baumann, 2014; Edmondson, 2011; Ratcliffe, 1997; Khanna et al., 2016; Loewe and Dominiquini, 2006; Luqmani et al., 2017; Madsen and Desai, 2010; Magazzini et al., 2012; Marzocchi and Ramlogan, 2019; Rhaiem and Amara, 2021; Sawng et al., 2019; Scaringella, 2017; Shepherd and Kuratko, 2009; Svidronova et al., 2016; Xiong et al., 2020	Failure as Event
• Corporate factors also influence participation in, and success of, innovation. • We over-weight (the importance of) failure – loss aversion	Failure Avoidance	Banyte and Salickaite, 2008; Barnett and Freeman, 2001; Bergek et al., 2008; Cannon and Edmondson, 2001; Gershon, 2013; Madsen and Desai, 2010; Potts, 2010; Shepherd and Kuratko, 2009; van Mierlo et al., 2010; Yang et al., 2020	

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