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Psychological factors influencing technology adoption: A case study from the oil and gas industry

Ruby Roberts [a,*], Rhona Flin [b], David Millar [c], Luca Corradi [c]

[a] Aberdeen Business School, Robert Gordon University, Garthdee, Aberdeen, AB10 7QE, Scotland, UK
[b] Aberdeen Business School, Robert Gordon University, Aberdeen, Scotland, UK
[c] The Oil and Gas Technology Centre, Aberdeen, Scotland, UK

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ABSTRACT

People have the power to make an innovation a success or a failure. Corporate decision makers act as both facilitators and barriers to the introduction of technologies into their organisations. Psychological factors clearly have an impact on their decisions and acceptance behaviours, but these have not been fully explored. Consequently, an understanding of these factors is essential for organisations who wish to accelerate technology adoption as well as for innovators who face numerous barriers when introducing their new products to the industrial market.

The upstream oil and gas (O&G) industry has been characterised as reluctant to adopt new technology. The analysis of three technology introduction case studies in the UK offshore O&G sector (including interviews with 22 personnel involved in developing and commercially buying new technology) confirmed the influence of 15 psychological factors on organisational technology adoption decision making. These have been organized into a framework (P-TAF) consisting of six categories of psychological constructs, namely: personality, attitudes, motivation, social, cognitive, and organisational factors. With further development, this preliminary framework can be used to develop interventions that support the successful technology uptake in O&G and in other sectors experiencing resistance to the introduction of new technology.

1. Introduction

Innovation continues to transform the global market and the modern workplace, offering potential solutions to the challenges that organisations face (e.g., climate change, remote working, circular economy, and cyber security). This has been illustrated most recently with the Covid-19 pandemic in which technology plays a key role in containment and mitigation strategies (e.g., testing and contact tracing; Whitelaw et al., 2020) as well as essential healthcare equipment (Javaid et al., 2020). Many people work tirelessly towards developing innovations in a fiercely competitive and rapidly changing digital world. Yet their creations are only successful if they are adopted and used (Frambach and Schillewaert, 2002). Reluctance of organisations to adopt new technology can result in significant costs, such as through loss of competitive advantage and potential revenue (Makkonen et al., 2016; Prybylski, 2019). With the wave of digitalisation spreading across many industries including transport, healthcare, and energy production, understanding the organisational innovation adoption process, and the factors which influence it, has never been more relevant (Nambisan et al., 2019).

Psychological barriers to introducing new technology in industry include managers' attitudes and resistance to prototypes being trialled on their worksites, their concerns about being an early adopter if there could be productivity risks, as well as end-users' reluctance to change familiar ways of working (Kratzer et al., 2017; Roupas, 2008). Understanding how these psychological factors influence technological innovation adoption in industrial consumers is vital to support the successful introduction of new products and systems.

Whilst market, economic and organisational factors are frequently discussed within the innovation literature, psychological factors can also act as powerful facilitators or barriers to corporate and institutional technology adoption (Knobloch and Mercure, 2016; Makkonen et al., 2016). However, these are typically examined to a lesser extent. The term 'psychological' refers to the spectrum of factors pertaining to the mind and behaviour. Recognition of the psychological influences on technology adoption places a spotlight onto the individual decision makers who determine if a technology is to be introduced (or not) into

* Corresponding author.
E-mail address: r.roberts2@rgu.ac.uk (R. Roberts).

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their organisation. This individual is a central feature in technology adoption and acceptance models (e.g., Davis et al., 1989) and is particularly relevant within the B2B context where industrial/corporate consumers make decisions on behalf of a company. These 'gatekeepers' can be in formal roles, such as the managers and technical specialists who make the pivotal decisions to appraise, trial or adopt technologies for deployment in their organisations. However, they can also be in informal roles, such as those who determine whether to allow a company to give a presentation on a new product to their colleagues. The gatekeepers are often located at key milestones of the innovation process, with the potential to make a significant impact on the success or failure of a technology (Nochur and Allen, 1992).

An industry which exemplifies resistance to technological innovation is the oil and gas sector. Innovation is critical to its future success (Perrons, 2014; Wood, 2014), however, the road to adoption of new technological innovations is not as smooth as might be anticipated (Daneshy and Bahorich, 2005). Consequently, examining the consideration of new technologies in O&G offers an interesting perspective from an industry which must innovate to survive but is well known for its resistance to innovation. This article reports a set of three case studies (based on three product types) designed to explore the contribution of psychological factors that influence technology adoption, within the UK offshore oil and gas industry.

2. Psychological components of innovation adoption

Innovation adoption, and the factors which influence it, have been studied from multiple perspectives over the past five decades. Whilst a full review of this expansive research area is beyond the scope of this paper (see Meade and Islam, 2006 for a review), several key models should be highlighted in relation to the psychological component of innovation adoption. Rogers (1983) diffusion of innovation theory (DOI) became a seminal work, providing a framework to understand why new ideas and technologies are introduced and integrated (or not) into an organisation. His five-stage model of the innovation-decision process model (knowledge, persuasion, decision, implementation, and confirmation) included psychological factors such as personality characteristics, attitudes, uncertainty, and social norms (Rogers, 2003). This has been a highly valuable model for directing subsequent innovation research which has also identified additional psychological factors such as incentives (green energy; Simpson and Clifton, 2017) and leadership (education; Keengwe et al., 2009). Similarly, the Technology Acceptance Model (TAM, Davis et al., 1989; Venkatesh and Davis, 2000), which also incorporates psychological elements, has been valuable for predicting user acceptance of IT systems within the information systems literature. It was originally based upon the psychological Theory of Reasoned Action (TRA; Fishbein and Ajzen, 1975) in order to understand the acceptance behaviours associated with new information technologies through users' attitudes and subjective beliefs. Another psychological model was later added to the TAM in the form of the Theory of Planned Behaviour (Ajzen, 1991) by applying the supplementary component of perceived behavioural control (Davis et al., 1989). Throughout the model's refinement, further psychological factors have been added including social influence (Venkatesh and Davis, 2000), trust and risk (Pavlou, 2003). Although, it has been criticised for not recognising the role of emotional, social, and cultural components (Bagozzi, 2007). Whilst prominent models do recognize that psychological factors influence technology acceptance, they are not typically all incorporated within one framework for the business technology adoption context.

From an individual consumer perspective, psychological factors that have been identified as impacting on acceptance decisions include innovativeness (virtual reality in aeronautical assembly; Sagnier et al., 2020), trust and social influence (automated vehicles; Zhang et al., 2020). Perceptions of risk, social norms, image, and attitudes have also been found to influence rejection decisions (e.g., internet and mobile banking; Laukkanen, 2016). Research on managerial judgment and decision-making strategies at the individual level has identified psychological factors such as attitudes and social influences (e.g., Bazerman and Moore, 2017) and these apply to the technology adoption context (e.g., Streletskaya et al., 2020). However, across the literature on individual consumers, although psychological influences have been listed (e.g., Huijts et al., 2012), these concepts are typically not considered in depth or within a comprehensive framework that outlines the full spectrum of psychological factors.

Moving to the corporate level, several key organisational technology adoption models include psychological factors (e.g., Frambach and Schillewaert, 2002), such as within the acceptance of IT systems (Hameed et al., 2012). For example, trust in security has been identified as a critical factor for cloud computing acceptance (Schneider and Sunyaev, 2016). Risk aversion has been identified as a barrier to innovation procurement in a range of sectors (Uyarra et al., 2014). Characteristics of B2B transactions between industrial consumers may heighten the impact of psychological processes and influencing factors, as compared to B2C transactions. For example, the longer decision-making process within a complex procurement structure and greater reliance on expertise and credibility built on long-term relationships (Sethna and Blythe, 2016). Organisational innovation adoption is an active behavioural process undertaken by the constituent individuals (see Makkonen et al., 2016), consequently it is influenced by their attitudes, motivations, and social pressures (Roupas, 2008), as well as psychological factors operating at an organisational level (e.g., culture; Dziallas and Blind, 2019).

Despite inclusion across multiple literatures, the psychological factors are unevenly spread across models, theories, sectors, and applications (Keupp et al., 2012; van Oorschot et al., 2018), resulting in a level of confusion. There does not appear to be an integrated framework which outlines the potential psychological variables for business technology adoption. This could be valuable for many sectors which are experiencing resistance to technology introduction but need to embrace innovation to remain competitive (e.g., healthcare; Williams and Dickinson, 2010). In response to this gap, recent research has developed a new psychological technology adoption framework (P-TAF) within the oil and gas industry (Roberts, Flin, Millar & Corradi, in press) and it will be examined in this study.

2.1. Technology adoption in upstream oil and gas

The oil and gas industry still provides the majority of energy that is used in many countries (e.g. UK Government, 2019; EIA, 2019) by searching for and then producing hydrocarbons, often from remote and inhospitable locations, such as beneath the oceans. Historically, to cope with these hazardous and complex environments, the O&G industry has been innovative, developing and deploying a broad arsenal of technologies including intricate hardware, data analytics, remote monitoring, and drone technology for inspections. Some of the inventions which were developed for the O&G industry have been applied to other sectors. For example, seismic nodes which were designed for exploration have been used for monitoring earthquakes or Remotely Operated Vehicles (ROVs) developed for O&G subsea surveys are now used by scientists across the world (Jacobs, 2019).

In recent years, the industry has become increasingly competitive with multifaceted challenges, such as climate change, decommissioning, and a changing workforce (Opito, 2018; Perrons, 2014; Radnejad and Vredenburg, 2017). These issues, when combined with the significant risks of failure and the high cost of being a first user, have resulted in the industry gaining a reputation for being conservative and slow to uptake new inventions (Daneshy and Bahorich, 2005; Perrons, 2014; Wood Review, 2014; Bereznoy, 2018). To address these barriers, there have been recent attempts to encourage the sector to become more technology intensive, as can be seen with the accelerator programs, the significant increase in investment in start-up technology companies ($70 million in 2019; Jacobs, 2020), and internal corporate venture units designed to foster the development of innovative technologies in major producers (Masucci et al., 2020). Despite incremental improvements, it is critical that the industry accelerates technology adoption as it moves towards becoming an integrated energy sector (Oil and Gas Authority, 2019). The industry's residual resistance to technology adoption, provides an interesting opportunity to examine the technology adoption process.

Roger's DOI (2003) model also emphasised the importance of the level of innovativeness shown by the individual or organisation, with early adopters illustrating the greatest openness to new ideas and technologies. This is valuable within the context of O&G and psychology for two reasons. From an outward perspective, it appears that many organisations within the O&G industry can be characterised as late adopters. These organisations are slower to adopt products compared to other users, showing higher levels of resistance to innovation, and more skepticism towards new technologies. According to Jahanmir and Cavadas (2018), late adopter firms are particularly influenced by psychological factors, including attitudes and word of mouth. Evidence from O&G industry bodies reflect this, indicating that psychological factors play a key role in technology adoption, such as risk aversion (Wood, 2014), lack of ownership and leadership around technology (OGTC and ABB, 2018), combined with a reluctance to change (OGA, 2018). This is relevant beyond O&G as late adopters are becoming a larger and more influential consumer group (Wells, 2016), particularly in the context of digitalisation. To remain competitive, O&G organisations need to embrace technological innovation, but previous approaches to induce the acceleration of adoption do not appear to have been entirely successful. Consequently, the industry provides a unique opportunity to examine the psychological factors which influence technology adoption decisions.

2.2. Psychological technology adoption framework

To address the innovation adoption challenge within O&G, recent research has begun to examine the psychological factors that can influence technology uptake. As outlined above, psychological factors have been identified within the innovation management literature, however, they are often disparate and unevenly spread across different models, making it difficult to determine the key psychological factors which may influence technology adoption decision makers. Consequently, a set of possible psychological factors was initially identified from a literature review of studies from the oil and gas sector (Roberts & Flin, 2020), with reference to the key innovation adoption models mentioned above. This initial set was then revised on the basis of the findings from an interview study with key technology adoption decision makers in upstream O&G (e.g., senior and middle management, technology adoption consultants and representatives from start-up companies) to determine the psychological factors that influence technology adoption decisions. Thematic analysis identified 15 factors, organized into six overarching categories (called the Psychological Technology Adoption Framework P-TAF) representing major psychological constructs influencing technology adoption, (Roberts, Flin, Millar & Corradi , in press) as shown in Table 1 below.

Within this context, psychological is defined as pertaining to mind and behaviour and our primary unit of analysis is the individual decision maker (typically the corporate buyer or his/her representative). Consequently, this framework includes factors from three different levels of psychological enquiry: individual (e.g., personality differences and attitudes), social (e.g., subjective norms) and organisational (e.g., leadership) – all of which can influence technology adoption decisions. The interview data indicated that many of the factors are interrelated. For example, personality factors such as innovativeness may influence technology attitudes, risk perceptions, and leadership (and by proxy, organisational culture). Furthermore, there is a degree of conceptual overlap. For example, fear of technology failure can be linked to risk

Table 1
The preliminary Psychological Technology Adoption Framework (P-TAF): categories, factors, and definitions.

Category	Factor	Definition
Personality Factors	Individual differences in configuration of characteristics and behaviour that encompasses an individual's adjustment to life, including major traits, interests, drives, values, self-concept, abilities, and emotional patterns (APA Dictionary).	
	Innovativeness	An individual's orientation towards novelty and change, relating his or her willingness to try out new technologies (both in personal life and work life) (Hurt et al., 1977; Aldahdouh et al., 2019).
	Risk Aversion	The tendency, when choosing between alternatives, to avoid options that entail a risk of loss, even if that risk is relatively small (APA Dictionary).
Motivation Factors	The impetus that gives purpose or direction to behaviour and operates in humans at a conscious or unconscious level (APA Dictionary).	
	Personal Incentives	Perceived rewards or punishments (to be avoided) acting as drivers for behaviours, including desires to improve job performance, pay or promotion or to avoid redundancy (Gagné and Deci, 2005).
	Fear of Technology Failure	The motives and concerns about the consequences of introducing a new technology and its potential failure. Similar to fear of failure when risk taking (Atkinson 1957), often applied in a business context (e.g. Cacciotti et al., 2016) although in this case, relates particularly to the operational consequences than personal implications for the decision maker.
Attitude Factors	Mental evaluations that an individual forms about people, objects, events, or ideas, which can influence subsequent behaviour. Attitudes have three components: affective (emotions about the object); conative (influence on behaviour and actions towards the object); and cognitive (beliefs and knowledge about the object) (Ajzen & Fishbein, 2005; APA Dictionary).	
	Technology Attitudes	The evaluations that an individual makes about novel technical products including the people, objects, events, and ideas associated with their adoption (Edison and Geissler, 2003).
	Trust	The belief that an individual has towards people (or objects) regarding their ability, reliability, and truthfulness (Demolombe, 2004). In this context, trust is a belief about not only the technology, but all the stakeholders involved (e.g. the developers, managers involved in adopting new technology, leadership) (Ratnasingam, 2005).
Cognitive Factors	Mental processes that drive knowledge and understanding of the world, including attention, perception, memory, language use and problem solving (APA Dictionary).	
	Risk Perception	The gathering of information and making a judgement of the hazard level, and potential loss that could be incurred, in a given situation (APA Dictionary); it involves gathering information and making a judgement of the risk level, and potential loss that could be incurred.
	Technical Knowledge	The process of an individual recalling their domain-specific knowledge which contributes to his or her performance (Agarwal and Prasad, 1999).
	Perceptions of Certainty	The sense of surety that an individual has about the prediction of current or

(continued on next page)

Table 1 (*continued*)

Category	Factor	Definition
		future events and states (e.g., decisions, or actions), including the judged level of confidence about how the technology (Johnson and Slovic, 1995).
	Previous Experiences	The recollections of positive and negative experiences with technology and new ways of working (Agarwal and Prasad, 1999).
Social Factors	Refers to what can be called social cognition, in which people perceive, think about, interpret, categorize, and judge their own social behaviors and those of others (APA Dictionary).	
	Social Influence	Any change in an individual's thoughts, feelings, or behaviours caused by other people in relation to introducing new ways of working *(APA Dictionary)*.
	Subjective Norms	A perception that an individual has regarding whether people important to that individual (e.g., colleagues, supervisors) believe that he or she should or should not perform a behaviour (Ajzen, 1991).
Organisational Factors	This refers to the psychological factors that occur at the organisational level. An organisation being a structured entity (e.g., in business, industry, and services) consisting of various components that interact to perform one or more functions. (APA Dictionary).	
	Leadership	The values, behaviours, and attitudes of people in all positions of leadership and how this influences the organisational culture and behaviours of employees (Northouse, 2018; Hameed et al., 2012).
	Collaboration Culture	The specific aspect of organisational culture that relates to how people internally and externally work together to reach a shared goal (Dodgson, 2018).
	Technology Adoption Culture	The specific aspect of organisational culture that relates to how technology and innovation is valued within an organisation (Frambach and Schillewaert, 2002; Kratzer et al., 2017).

aversion, risk perceptions and perceptions of uncertainty. The data indicated that fear of technology failure in the O & G sector mainly concerned anxieties about the repercussions for the adoption decision maker of a technology failing. Consequently, it was deemed to fit best as a motivation factor i.e., a motive for not introducing a technology.

Given that many of the factors appear to be interrelated, there is likely to be a level of overlap between them. However, the prior interview study data, on which the framework is based, and psychological literature indicated that they were sufficiently disparate to be classified in this manner. For a full explanation of the categorisation of factors, see Roberts, Flin, Millar and Corradi (in press). Nonetheless, the framework would benefit from further application to test these categorisations.

The factors relate to early stages of adoption decisions and processes, e.g., a precursor decision to grant access to a technical or operational manager, inviting a start-up technology company to give an internal presentation to a potential client, or deciding to agree to a field trial (see also Afolayan and de la Harpe, 2020). The 15 factors are grounded in both the psychological and innovation literatures, with the labelling and definition of the main categories and component factors based on the terms used for these psychological constructs in the American Psychological Association *Dictionary of Psychology* (https://dictionary.apa.org/psychology) and the psychological literature. Some of the factors (e.g. technical knowledge) have been labelled using terms already applied to the concept by the oil and gas sector, in which case, the psychological term is given in the definition.

Given that this is a preliminary framework, additional evidence is required to confirm the components and to develop an understanding of how they operate. The case study method offers a means of gathering data in an attempt to refine and validate it within realistic, specific contexts. It may also provide further detail on the influence of the factors within different circumstances (e.g., well-established technologies compared to start-up company prototypes), to direct future actionable tools and recommendations.

3. Case study aim

A set of three case studies was produced with a dual purpose. 1. To refine the preliminary P-TAF by determining the indications of the factors within different circumstances in the upstream UKCS. 2. To identify the best practices regarding the control of the psychological factors' impact on successful innovation adoption. The findings could be used to inform interventions to support technological innovation uptake.

4. Method

A multiple-case study approach was used which allows investigation of phenomena in their general complexity and within their natural environment. Furthermore, it offers the opportunity for cross-case comparisons permitting a more vigorous explanation building process and understanding of contextual variables' effects (Chiesa and Frattini, 2007) which made it an appropriate method for this study. Following standard case study practices (Yin, 2017), a multi-pronged approach was taken by collecting data from several sources namely, interviews, document analysis, and observations (e.g., pitches, events, and online videos). To support the reliability of our study, these additional forms of observational data and documents were used to complement the interview transcripts through triangulation (Angrosino, 2007). This approach is commonly used for examining technology adoption, such as within healthcare (Kyratsis et al., 2012), automated driving (Horberry et al., 2017), and manufacturing (Trott and Simms, 2017).

4.1. Case selection

One of the aims of the study was to understand how psychological factors influence technology adoption decisions in different circumstances. Therefore, the intention was to select cases which represented different aspects of the innovation adoption process, such as different technology readiness levels (Mankins, 2009). For example, early-stage start-ups trialling innovative technology (TRL7), companies with technologies which were reaching commercialisation (TRL8), or at market technologies which were adopted by some and resisted by others (TRL9 and adoption). Potential cases were initially selected based on a purposeful sampling technique (Creswell and Poth, 2016) to capture a wide range of experiences of introducing new technology into O&G. Selection criteria were based upon the study aims and consisted of: companies working to introduce new technologies into the UK O&G industry; technology developed up to readiness level 7 implying that they were nearing commercialisation and potential introduction of the technology into an organisation; experiences suggesting barriers to adoption; and sufficient time to commit to the case study. An initial list of companies and contacts was produced by O&G industry specialists (LC and DM) within the sponsoring organisation. Once potential companies were identified by the research team, they were invited to participate in the study through the UK Oil and Gas Technology Centre contacts. Whilst this may have influenced the potential sample, the initial contact list (28 companies) was sufficiently large, (i.e., covering a wide range of different services and readiness levels) to provide a representative sample.

Despite twelve companies initially agreeing to take part, after several months of polite requests and flexibility over the data collection (e.g., Skype interviews, flexible times, and locations), only two companies enabled access for data collection. Furthermore, a number of the companies had raised concerns about providing contacts from potential clients to give a decision maker's perspective (e.g., discussing slow uptake of a product might reflect poorly on the developer and/or potential client). It was therefore decided to develop a third case by examining a technology which has experienced recent technological advances and has been introduced by some O&G operators but not others. As this type of technology is offered by more than one company, it afforded the opportunity to examine this service from multiple perspectives (e.g., the technology service providers, operators).

Whilst recruiting companies for the study was difficult, the addition of the third case was beneficial as together the three cases represented different aspects of the innovation adoption process – case 1 was an early-stage technology in the process of validation; case 2 was a company which had commercialised their technology with initial contracts with major operators; and case 3 was an established set of technologies which had been adopted by some but not by others.

Approval for the study was granted by the university department's Ethics Committee. All the technologies are UK-based but may be distributed internationally (see Table 2).

4.2. Data collection

Before commencing data collection, case study candidates were informed that taking part would entail interviews, as well as sharing relevant documents and/or for the researcher to conduct observations, where appropriate (e.g., confidential documents). The data collection (June–September 2019) consisted of face to face and phone interviews, live observations, and document analysis. The interviews were audio recorded and transcribed for analysis.

The main company contact (e.g., the original technology developer or CEO) was asked to take part in an initial interview lasting approximately 2 h and split into multiple sessions for convenience. As based upon Yin (2017) guidelines, a timeline was produced for each case during these initial interviews with the main contacts. This consisted of key dates, events, interactions, difficulties, and information relevant to the technology adoption journey. It was reviewed by at least one of the key stakeholders from the company to confirm accuracy. The timeline provided the basis for the subsequent interviews which asked about individuals' jobs, their opinions on the technology and experiences of introducing this new technology into the UKCS, including barriers and facilitators that impacted on their experience. The remaining interviews with other employees and stakeholders each lasted approximately 45 min. This included interviewing potential gatekeepers and product champions. The interview schedule, including the questions asked in the initial and subsequent interviews, can be found in Appendix A.

The types of data collected for each case study are shown in Table 3. A total of 22 interviews were conducted with an average interview length of 47 min (range 25–120 mins) The total time for all the interviews was 16 h and 55 min.

In order to get the decision maker's perspective, the interviews included those in potential decision-making roles such as prospective clients or technical specialists who may act as initial gatekeepers (e.g., technical or operational managers who may agree to a trial). For case study 1, two decision makers were interviewed; for case study 2, two decision makers were interviewed; for case study 3, six decision makers were interviewed. These decision makers could act as potential gatekeepers, allowing the technology to be trialled or introduced into their organisation or block any further uptake activities. Decision makers represented approximately half of the sample. Observation data were collected on six occasions in the form of field notes (Morgan et al., 2017) gathered during live observations (e.g., pitches) and video recordings (e.g., video presentations). The total length of observations was 120 min. Nine documents were gathered from both confidential company sources (e.g., internal reports) and publicly available sources. The total length of the documents was approximately 200 pages and where publicly available, these are included in the reference section (the details of the blog documents are not included to maintain anonymity). The entire documents were initially read to provide a background on the cases and then analysed using thematic analysis (see below) to identify the underlying psychological factors (Rapley, 2018).

4.3. Data analysis

The interviews were recorded, and notes taken. The interview coding and analysis was conducted by the two psychologists (RR and RF).

The transcribed interviews, observation notes and documents were analysed using an adapted version of Braun and Clarke (2006) Thematic Analysis via the software program Nvivo 11 (QSR International, 2013). This is a structured method for identifying, analysing, and reporting themes within the interview, observational and document content. This process followed a deductive, content analysis method to identify the underlying psychological factors that impact on technology adoption in the UKCS. An initial coding framework was developed with reference to the P-TAF factors with a coding scheme of 15 codes, each representing a psychological factor. During this process, the coders remained open for additional or alternative psychological codes.

Each time a theme was identified within the text, this was coded and is reflected in the frequency data (Torrens, 2018). The frequencies for the interviews, observation and document analysis data are shown in Table 3. Frequencies should not be taken to imply importance, issues may not be mentioned as interviewees may believe that they are obvious, unimportant or of a sensitive nature. Interviewee quotes are included throughout the case studies to provide a rich description of the themes discussed. Each case study interviewee number is shown in brackets after the quote and the psychological factors are shown underlined.

To identify the psychological factors and determine how they influenced the technology adoption decision outcomes, each case was analysed separately. This allowed immersion within each case before examination of the psychological factors identified across the whole data set. Discussion of the results with the non-psychologist authors provided a valuable opportunity to examine the categorisation of the factors.

Data availability: Data analysis methods are included in the section above and the semi-structured interview schedule is in Appendix A, however, to maintain the confidentiality and anonymity of the interviewees, as per our ethical requirements, individual data will not be made available.

5. Case study results

The analysis of the interview data, observations, and document analysis identified 15 factors across the three cases which could be allocated to the six psychological categories, labelled personality factors, attitude factors, motivation factors, cognitive factors, social factors, and organisational factors as per the P-TAF shown in Table 1. These were regarded as influencing the introduction of the new technologies, outlined in the three case studies, into the UKCS O&G industry. No additional psychological factors were identified.

The following sections present the results of the three case studies. This includes a brief description of the companies and technologies within each case. Given the focus of analysis is on the decision maker, the results include reference to the gatekeepers, how they were

Table 2
Case study details.

Case Study	Stage	Technology	Company size (employees = n)
1. Well Sealant	Early-stage technology; in process of validation with several operators.	One technology; potential to be adapted to multiple applications	3
2. Subsea Well Construction	Commercialisation; several contracts with tier 1 operators.	Two technologies developed in parallel.	8
3. Non-Intrusive Inspection	Well established range of technologies available at market.	Several different NII techniques including ultrasonics (UT), phased array ultrasonics (PAUT), radiography (RT).	Wide range of companies offering NII services.

Table 3
Data collection methods for each case study.

Case Study	Data Collection					
	No. of Interviews	Interview Total length	Roles of individuals Interviewed	Observations	Documents	Total no. of sources
1. Well Sealant	5	225 mins	CEO (1), company staff (2). Technical/operational managers of other organisations (2 – decision makers)	30 mins (live) + 1x online video (15 mins)	3 (online blogs)	10
2. Subsea Well Construction	6	280 mins	CEO (1), company staff including directors (3). Technical/ operational managers in other organisations (2 – decision makers).	2x online videos (20 mins each)	1 (internal document)	9
3. Non-Intrusive Inspection	11	510 mins	Asset integrity managers from operators (3 – decision makers) and contractors (3 – decision makers). NII service company technical specialists (3-developers). Technology centre advisors (2).	2x online videos (15 mins +20 mins)	4 (publicly available industry reports)	17

perceived and their role in technology adoption decisions.[1] In this context, gatekeepers may be in formal roles (e.g., managers and technical specialists) who make decisions to appraise, trial, or adopt the technologies. They can also be in informal roles and who indirectly influence the decision-making process (e.g., agreeing to and then setting up a pitch presentation to their colleagues). A summary of these results, as well as the findings on psychological facilitators and barriers, are given at the end of the section.

5.1. Case study 1: Well sealant

This company focuses on well barrier solutions and the technology is a well sealant which is pumped into the subsea wellbore. This can be used to seal off unwanted fluids (e.g. water or hydrocarbons) and leaks from the seabed around the wellbore. The technology had originally been developed for well abandonment and decommissioning (i.e. where a well is blocked off so that it can be safely closed, and the subsea infrastructure and equipment can be taken out of use). However, the company decided to pivot after receiving considerable resistance towards the product for well abandonment and began to explore its use for well integrity instead (i.e. maintenance of an active subsea well). From 5 interviews, document analysis and 30 min of observations, 14 out of the 15 factors were identified (all six categories were represented) as influencing the development and early deployment of this technology (shown in Table 4).

Personality differences were identified in the context of the innovativeness of technology gatekeepers and decision makers. The CEO perceived that gatekeepers (e.g., individuals who may set up a presentation, provide access to a budget holder or decision maker, or managers who may agree to and set up trialling the technology) and potential gatekeepers tended to have a mix of innovativeness. In some instances, he judged them to be innovative, open minded and comfortable with new technology. This was summarised by the CEO below:

> *"You've got the generation of people who have grown up using computers and programming and coding and using iPads and wireless technology. Generally, they have got another twenty, thirty-plus years in their career, they're looking at going "yeah, this could be a problem I'm going to have to deal with in the future. Yeah, let's look at something now."* (CS1–I1: developer).

This was contrasted by gatekeepers and potential decision makers who appeared to be risk averse and were uncomfortable about new technology, being described as *"dinosaurs"* (CS1–I2: developer).

Initially the CEO experienced negative technology attitudes in the form of gatekeepers and decision makers resistance towards their new product being used for well abandonment. In one example, he spoke about talking to a large operator within the UKCS who had such an aggressive, anti-technology attitude that he felt they "*pretty much got chased out*" (CS1–I2: developer). These attitudes, in part, led to the company changing from promoting the well sealant for well abandonment to a well integrity application. This strategy proved to be effective, and the technology attitudes they encountered became positive with prospective clients becoming more open and interested in the product. One potential decision maker and gatekeeper noted that "*We thought we might have faced quite an uphill battle to get some of the larger organisations even interested in playing in this area, but I think the tide is almost changing with regards to the attitudes around using solutions developed by start-up companies*" (CS1–I4: decision maker). One of the developers suggested that this positive attitude change may be a result of "*[companies] possibly being hit on the bottom line when they've not adopted these technologies, so attitudes have definitely improved in the North Sea*" (CS1–I3: developer).

The developers perceived some of the gatekeepers with whom they interacted to hold significant power over the outcome of the interaction (e.g., whether their technology may be trialled into the gatekeeper's organisation), and that was heavily influenced by the gatekeeper's attitudes and motivations (see below). However, this power was not perceived to be effective outside the gatekeeper's sphere of control (e.g., their department or organisation) and should the developers encounter a resistive gatekeeper they would "*not bother talking to you, we'll work round you, talk to someone else, work elsewhere*" (CS1–I2: developer).

A key influencing factor on gatekeepers' negative technology attitudes and decisions that he encountered was motivations. This included gatekeepers' and decision makers' personal incentives about job

[1] We would like to thank one of the reviewers for highlighting the critical role of the gatekeeper and the data were re-examined to provide a fuller examination of the gatekeeper and product champion's roles, the powers perceived to be assigned to them, and the psychological factors which influence them.

Table 4
The total number of times each P-TAF factor was mentioned in the interviews, observations, and document analysis.

Category	Factor	Number of times coded across data			
		Total (Observations & Document Analysis)	Case Study 1: Subsea well construction	Case Study 2: Well sealant	Case Study 3: non-intrusive inspection
Personality Factors		27 (0 &3)	8	16	3
	Innovativeness	*24 (0&3)*	*7*	*14*	*3*
	Risk Aversion	*3 (0&0)*	*1*	*2*	*0*
Motivation Factors		**59 (0&4)**	**20**	**9**	**30**
	Personal Incentives	58 (0 &4)	20	9	29
	Fear of Technology Failure	1 *(0&0)*	0	0	1
Attitude Factors		**111 (4 &3)**	**35**	**32**	**44**
	Technology Attitudes	67 (0&1)	13	19	35
	Trust	44 (4&2)	22	13	9
Cognitive Factors		**235 (5& 29)**	**59**	**59**	**117**
	Risk Perception	*145* (5&14)	*45*	*43*	*57*
	Technical Knowledge	*62* (0&11)	*6*	*9*	*47*
	Perception of Certainty	*15 (0&0)*	*4*	*4*	*7*
	Previous Experience	*13* (0&4)	*4*	*3*	*6*
Social Factors		**123 (6&2)**	**65**	**26**	**32**
	Social Influences	111 (6&1)	60	26	25
	Subjective Norms	12 (0&1)	5	0	7
Organisational Factors		**117 (0&4)**	**35**	**24**	**58**
	Leadership	*32* (0&1)	*4*	*3*	*25*
	Collaboration Culture	*16* (0&4)	*2*	*0*	*14*
	Technology Adoption Culture	*69 (0&0)*	*29*	*21*	*19*

security and being unwilling to take a risk or make a change towards the end of a contract or career. The developer recognised that adopting new technology may represent further work for companies, consultants who are working with traditional methods "*may feel threatened*" (CS1–I2: developer), and summarised gatekeeper's potential motivations as below:

> *"There are other aspects of, what's in it for these guys? And we talked about the motivations, and is it just a headache? Is it just a risk? Is it unhousing one of their best friends that takes them out to play golf every year? You know, they've got a corporate box at football that they go to, stuff like that."* (CS1–I2: developer)

Trust was identified as a key facilitating factor to work against negative attitudes and motivations. The well sealant company created trust with potential gatekeepers and clients by being honest about their technical experience. "*And just being open and speaking about the opportunity for any new technologies, not ours, not pushing it*" (CS1–I3: developer) appears to have been an effective method for growing credibility. Fear of technology failure was not identified within the data.

When deployed for well abandonment, the sealant also allowed large sections of equipment to be left in the seabed, offering considerable savings (e.g., rig hire, days required to pull tubing out). Consequently, *"if you get it right, there is a billion-pound prize out there for industry"* (CS1–I5: decision maker). However, the gatekeepers and decision makers recognised that in some situations risk perception was too high for well abandonment as should the sealant fail, there could be significant consequences. *"If you're putting it as a permanent barrier, then what you're saying is in perpetuity that barrier will hold any hydrocarbons from escaping to the environment, and therefore you have to qualify that barrier against Oil and Gas UK guidelines for barrier materials. And until you do that, nobody's going to accept it"* (CS1–*I5:* decision maker*)*. This may in part be due to the gatekeepers and decision makers perceived uncertainty associated with such a long period of time. *"There's a psychology of forever"* (CS1–I3: developer) that makes people nervous.

The company pivoted by considering alternative applications of the sealant, including well integrity as *"it's a lower risk, and it's not a permanent integrity part of the well, and if the water ultimately comes back in, you're no worse off than you were in the first place, and hopefully it's lasted for a while and you've got more oil out"* (CS1–*I5:* decision maker*)*. In addition, they recognised that applying this sealant to land rigs would reduce the risk and cost involved to the operator. As a result of this new strategy, several managers (acting as gatekeepers and potential decision makers) were keen to use the technology for current problems and upcoming campaigns, leading to field trials. Gatekeeper's negative previous experiences of deploying technologies that were perceived to be similar were also found to be influential. Technical knowledge was an influencing factor upon risk perceptions and technology decision making, particularly that of gatekeepers to be able to assess the relative value that the technology may offer the organisation. It was noted that there was a need for further knowledge to support effective decision making regarding using the well sealant for well integrity - *"we need to rewrite guidelines that we can get these materials in the right space"* (CS1–*I5:* decision maker*)*. One-way of doing this was to use hands-on demonstrations to increase familiarity during a pitch:

> 'He uses a demonstration to visually demonstrate how the product works by mixing a powder into a clear flask of water and stirring with a coffee stick – he later tips the flask confidently to show the fluid has set. The audience responds well with sounds of exclamation' (CS1-Observation Notes 1 (observing developer)).

Social factors including social influences and subjective norms appear to have shaped the success of technology uptake within this case. Developing a broad professional network was highly valuable for the CEO, using connections from previous roles to conduct initial customer validation and gain access to potential clients. This included building relationships with the gatekeepers and decision makers to understand the problems that they are facing - *"the most success I've ever had is where I've not even opened the computer, you sit there with a notebook, you talk about what you can do, what their problems are, and you see if there's any common ground"* (CS1–I1: developer). Taking part in an accelerator programme meant that "*you're not just a single entity on your own, you're with a group of other companies at a similar stage, the visibility that he got was probably a lot higher than what he was able to achieve alone*" (CS1–I3: developer). Subjective norms around well abandonment appear to have been a potential barrier to uptake of the well sealant. Typically, standard practices focus on removing any materials downhole and using cement as the go-to material. Whilst there have been changes in industry norms recently, there still appears to be a reluctance to change traditional behaviours. One of the developers articulated as "*I've been warned not to challenge the* status quo *and I just threw a cat in amongst the pigeons and legged it, you know?"* (CS1–I3: developer).

The developers assigned power to the impact that product champions could have on the success of their technology. Fostering a professional network of individuals who recognised the value of the technology was crucial for creating product champions who bought into the technology and provided potential routes to trial. In particular, "*within the operating companies that you'll end up with the champion in the wells team like "this is great, really want that""* (CS1–I4: decision maker). In one instance, a product champion was able to secure the company a trial on a well in another country, through the champion's network of contacts within the client company. This provided the company with early validation data off the back of which they secured further trials and eventually contracts. The reporting lines were different depending on the individual champions as *"you obviously have different communication with different departments in the operating companies so the in wells might be like "this is great, really want that" but I need to talk to so and so to get it signed off"* (CS1–I2: developer). In contrast, individuals could harness their social networks to block the uptake of the well sealant within a company, who "*really got the bit between his teeth to try and cause some problems*" (CS1–I2: developer). The developer termed these *"product snipers"* (CS1–I1: developer).

The overall industry technology adoption culture around innovation was identified as a potential barrier. Developers "*can create all the new solutions to industry problems, but unless people within the oil & gas operators are willing to be innovative themselves, and try something different, then things will never change*" (CS1–I2: developer). *Collaboration culture* was also briefly mentioned by the CEO regarding how he would like to see his own company work internally. Leadership is a fundamental driver for that cultural change in which they send out a message at the top level of the (customer) company and pass this down throughout the organisation.

5.2. Case study 2: subsea Well construction

The company focuses on well construction technologies that aim to save rig time with two technologies it developed. Subsea wellbores require complex engineering technologies, equipment, and processes to build these structures to gain access to hydrocarbons. The "Downhole Technology (DownholeT)" was developed first to support more efficient cementing operations (i.e., the cementing of the metal casing tubes into the seabed and below). The "Subsea Technology (SubseaT)" was developed about a year later with the aim of allowing operations within a wider 'weather window' for subsea operations (i.e., the technology allows normal operations, which would otherwise halt during poor weather). A further portfolio of technologies has subsequently been created but the case study will focus upon the first two. As these were developed in parallel within the same company, both technologies were analysed together. From six interviews, two online video observations and document analysis, 12 out of the 15 factors across the six psychological categories were identified as influencing the introduction of these two different well construction technologies (see Table 4).

Personality characteristics were identified in the context of the innovativeness of the gatekeepers, product champions and adopting organisation leadership. For example, it was reported that the product champions for these devices were typically open minded, innovative individuals. In some instances, technology decision makers were risk averse and displayed a "*fear of the unknown*" (CS2–I5: decision maker). In addition, it was found to be valuable to be able to identify the relative innovativeness and risk-aversion of potential contacts during early trials and throughout the commercialisation process, such as clients, end-users, and technical experts. One of the developers suggested that it was valuable to *"know who is innovative - these are individuals who are willing to try something. But then identifying those who perhaps are not innovative and are conservative, and just manoeuvring round them."* (CS2–I3: developer)."

In terms of the DownholeT, gatekeepers within the two potential customer companies who sponsored trials had positive technology attitudes, recognising that whilst it would not make a radical change to well construction, the technology could make a significant saving for well construction budgets in a relatively straightforward way. These gatekeepers' attitudes facilitated the positive technology decision to conduct the field trials - *"it was low hanging fruit, and so they were the ones that jumped at the first instance" (*CS2–*I2:* developer*)*. However, once the CEO took the technology out to market, he was met with the familiar reluctant attitude that *"they didn't want to be first, they couldn't take the risk, or were unsure about committing so they said, "you need to go away and prove it"" (*CS2–*I6:* decision maker*)*. An attitude preferring the status quo and being comfortable using current practices was likely a barrier to adoption.

The CEO perceived that gatekeepers, and their attitudes, had the power to facilitate positive technology decisions within their context (e.g., within their own organisations or social groups) as "*when they were on board, doors opened more quickly*" (CS2–I1: developer). Alternatively, where negative technology attitudes persisted, decision makers could act as powerful blockers to any further actions or uptake, as illustrated by the example below:

> *"Most people went away from the project thinking that was good. There was one guy who was headed back to Norway where he was working, and he went back still "this was a waste of time, we shouldn't have done it." The rest felt there was a lot of benefit. He was quite keen that anything went wrong was blamed on the tech, even if it wasn't. So, sometimes you have to agree to disagree and he was a real challenge."* (CS2–I5: Decision maker).

In these situations, the developers communicated that they would "*work around*" (CS2–I3: developer) these gatekeepers to reach other potential champions or decision makers who may be more inclined towards the technology. Furthermore, it was not just the attitude of a single gatekeeper or decision maker that could have an impact on a trial or outcome but of the wider decision-making structure. Both developers and decision makers recognised the wider context. "*Breaking down the barriers that might be in [an operating company] means trying to get the contacts of everyone involved, trying to convince them, trying to convince your line management – it's what we have to prove and get the confidence and qualification of the product."* (CS2–I5: decision maker).

Developing a sense of trust between the developer and potential clients, as well as for the credibility of the technology was found to be crucial. Trust played a key role in getting support for field trials and subsequent contracts for both the products. *"A lot of it comes down to trusting the individual and their capability to deliver, so somebody who is new has to prove themselves" (*CS2–*I6:* decision maker*)*. One of the company directors recognised that fostering trust between the developer and the clients (e.g., gatekeepers and potential decision makers) is imperative for early-stage companies as *"Concerns regarding the customer is multiplied by at least a hundred time when it's a start-up compared to [a tier 1 service company]"* (CS2–I4: developer). Credibility could also come in the from promotional materials such as the videos of the SubseaT trials which were "*filmed in the workshop with the tooling in the background, increasing the credibility of the CEO*" (CS2 – OBS2: observing developers and decision makers)". Having two companies involved in the DownholeT trials, increased the sense of credibility of the technology in which the expertise of each company endorsed the involvement of the other - from one company's point of view, *"oh, they're doing it, so it must be good"* (CS2–I2: developer) (see Social Influences below).

In terms of SubseaT, initially, a supermajor had initially shown interest in the product recognising that it could solve a problem that they currently had in terms of poor weather. However, personal incentives changed when the company experienced a merger. The individuals who had originally been gatekeepers and product champions changed their priorities, motivated by individual concerns including job security: *"From a psychology respect, people do business with people, and if people's reputations, jobs, mortgages, are on the line, do they want to stick their head above the parapet?" (*CS2–*I5:* decision maker*)* Nonetheless, the clear value proposition continued to foster positive technology attitudes towards the SubseaT: *"Doors opened up quicker because the technology was easy to articulate. So, people were like "oh, that's cool. Really awesome" (*CS2–*I2:* developer*).* Fear of technology failure was not identified within the data.

The DownholeT offered to improve efficiency of cementing operations but initially it was *"a bit more of a tricky value proposition to comprehend or to easily articulate in a sentence or two in the elevator pitch" (*CS2–*I1:* developer*).* This made it much more difficult to sell the idea of the DownholeT and this influenced the risk perception. It was through market validation with the clients during product trials that the value proposition was more clearly expressed and that in some circumstances the DownholeT was perceived to be lower risk than the traditional solution. One of the developers articulated the importance of identifying gatekeepers and champions as "*You've almost got to find the right people that just get it, just understand. It does sometimes feel like a roll of the dice*" (CS2–I1: developer). It is worth noting that sponsoring companies' decision makers and product champions saw the value of the product in the long term for use in another basin and were perceived to be de-risking the trialling of it by doing it in the UKCS. "*It was more taking a long term view of [it], doesn't offer a great benefit right now, but if we combine it with various other things and we take a longer term view, that's where we can start to see the significant benefit*" (CS2–I5: decision maker).

The SubseaT offered to open-up the weather window for well operations. This value proposition was much more comprehendible, and the company had a prototype in which clients could tangibly understand how it worked. However, should it fail, the risks such as the financial consequences could be significant in terms of damage to the subsea architecture and lost production time. The developers felt that "*given the risk profile, it's just not something that people [gatekeepers and decision makers] want to take on in the first instance*" (CS2–I3: developer). "*And that's the dichotomy of introducing technology that will save rig time, because if it doesn't go right, it may cost you more time*" (CS2–I4: developer).

Having tangible prototypes that could be touched, footage of the technologies in action from the field trials and involvement from several stakeholders helped to reduce decision makers' perceptions of uncertainty and partially de-risk the technologies. In addition, having a pair of sponsoring companies helped to reduce the perceived risk of being first – *"they probably did feel as though they were sharing the risk because it was like "we'll support the yard test", and then both people can understand the learning from that" (*CS2–*I6:* decision maker*).* A lack of the requisite technical knowledge required to accurately assess the risks and negative previous experiences were also found to act as potential barriers. In particular, the technical knowledge level (e.g., in relation to that technical area) and prior technology adoption experiences (e.g., in general and of deploying technologies which were perceived to be similar) of gatekeepers and decision makers were found to be influential.

Social influences also impacted on the technology journey at a broader level. There was a need to understand the social group involved in making the technology decision: "*At the end of the day, who is the buyer? You've got to convince the drilling engineer who is putting the program together, you've also got to convince his boss, the drilling manager. And then his boss is the asset manager. So, you have to make sure that when you're talking to one customer, you're talking to different arms of the one customer so that all of those risks and all of those buyers who are inputting to the buying cycle are also covered*" (CS2–I5: decision maker). Examples of positive social influence include early engagement with end-users which was valuable for both the DownholeT and SubseaT to provide initial market validation and gain endorsement from the operator community. As a result, the CEO fostered a broad professional peer network of connections with "*the business growing organically through that network*" (CS2–I2: developer). The use of social influences to the company's advantage was also seen in a promotional video about the trial of the DownholeT in which it 'includes interview footage of representatives from both [operator company] and the [sponsoring company] talking about the technology, what problem it addresses and its value' (CS2-Observation 2 (observing decision makers)). Subjective norms were not identified within the data.

Product champions within these sponsoring organisations and potential clients were fundamental for the successful technology outcomes. *"The big organisations get that reputation of being the reluctant ones to move forward and change, but I think ultimately, it's not necessarily the organisation, it's usually the individual that drives it forward in an organisation" (*CS2–*I6:* decision maker*).* The developers placed significant value on the impact that product champions could have on the successful outcome of a meeting, trial, or decision to commercialise. For example, "*from essentially not going anywhere, you get a couple of calls, and the consequences of those couple of calls are incredible*" (CS2–I4: developer). The CEO illustrated the impact that having (or not having) a champion could have on the success of a technology:

> *"I suppose the difficulty was then that we didn't really have that internal champion to the same extent we did with XX at [operating company] or XX at [operating company] for the SubseaT. The [operating company] team were not at the same level of commitment from a champion perspective for the DownholeT and not having that onus and feeling of ownership of the technology slowed things down*" (CS2–I2: developer).

Organisational level factors were identified as influencing the response to the technologies. Of the two companies involved in the DownholeT trials, it was perceived that the smaller operator had a positive technology adoption culture and that *"trying something new, this was bread and butter to them"* (CS2–I3: developer). Whereas the supermajor had a less innovative technology culture and that the drive to innovate came from senior leadership within the organisation *"saying we want to try this technology for the following reasons and we'll endorse you going and trialling it"* (CS2–I4: developer). Similarly, for the SubseaT, the drilling operator had developed a reputation for being an innovator and that they *"liked the kudos"* (CS2–I4: developer) that it gave them. Innovation was a key part of their culture, vision, and goals *"with their own mindset that has got a much more aggressive weighting towards new technology and accepting that value*" (CS2–I5). *Collaboration culture* was not identified within the data.

5.3. Case study 3: Non-intrusive inspection

This case deals with a technology called Non-Intrusive Inspection (NII) and is used to inspect assets such as pressure vessels or tanks for the presence of corrosion (or other defects and conditions). This type of technology has been previously used within process industries, but only recent technological advances have offered significant financial benefits for application within O&G. A range of NII technologies are provided by several companies rather than being exclusive to one source. The traditional inspection method is for personnel to enter confined spaces (e.g., vessels) to conduct an Internal Visual Inspection (IVI) which means that the process must be stopped to allow this. NII is a maintenance technique that refers to inspecting with scanning technology so that the equipment to be tested can remain in operation rather than shutting it down as worker entry is not required. Methods of NII include ultrasonics (UT), phased array ultrasonics (PAUT), radiography (RT). From eleven interviews, two online video observations and document analysis 14 out of the 15 factors across the six categories were identified as influencing the introduction of NII technologies in the UKCS offshore oil and gas industry (see Table 4).

There was minimal reference to personality traits within these interviews although it was mentioned that inspection engineers (acting as gatekeepers and decision makers) who were perceived as innovative tended to respond more positively to NII. Risk aversion was not identified in the data. This is likely influenced by risk perceptions, technical knowledge, and technology attitudes (see below).

There was a mix of technology attitudes expressed towards the introduction and adoption of NII. On one hand, there appeared to be a positive recognition of the value that NII offers but this was balanced by an attitude that did not see the value in changing current practices. '*There was little appetite for change*' (Document example from OGTC & ABB Phase 1 Report) was a common sentiment. A lack of engagement in the technologies available and an attitude of "*we've always done it this way*" (CS3–I10: decision maker) further illustrated a negative bias towards NII. However, there is evidence that this technology attitude is beginning to change with many organisations now engaging with NII and shifting their procedures to reflect that.

The developers perceived some of the gatekeepers which they interacted to hold significant power over the outcome of the interaction (e.g., whether their technology may be trialled into the gatekeeper's organisation), and that was heavily influenced by the gatekeeper's attitudes and motivations (see below). However, this power was not perceived to be effective outside the gatekeeper's sphere of control (e.g., their department or organisation) and should the developers encounter a resistive gatekeeper they would "*not bother talking to you, we'll work round you, talk to someone else, work elsewhere*" (CS1–I2: developer).

The results indicated that the developers of the NII technologies perceived that some of the gatekeepers which they interacted with held substantial power over the interaction (e.g., whether the gatekeeper's organisation would introduce one of their technologies) but much less so over the overall success of the technology. This was in part due to the changing attitudes towards NII within the industry. As one NII developer put it "*there has been a pretty substantial change, really noticeable change probably in the last five years or so, in terms of uptake. And change in attitude of some companies where historically they were saying "we're not going to do this" or "we're not going to do it on any scale, we'll do it on a special case basis*." Some of those companies are really shifting over to becoming real implementers" (CS3– I4: developer). In essence, as uptake increased across the industry, the power that individual gatekeepers and decision makers held to block adoption decreased.

Gatekeepers' and decision makers' technology attitudes towards NII were influenced by motivations and trust. Asset integrity managers make the inspection decisions, and it is their budget that pays for NII. The interviews suggested that there is limited trust in NII methods compared to traditional internal visual inspection. This included "*reservations, within the industry, about the competence of the NDT technicians [that] would clearly have an adverse impact on the further application of NII*" (CS3-Internal document). This could negatively impact decision makers' and users' ability to trust the service companies' competence to accurately interpret the NII data.

Typically, the benefits from NII are accrued by other departments, such as production, and in a longer time scale. Consequently, there may be little personal incentives to change if the decision makers do not receive any recognition for the value that they created. "*People aren't going to change without generally having a reasonable motivation*" (CS3–I9: decision maker). For example, "*We had one client who did NII on two vessels and it pretty much took up his entire budget for the year. So, it might have saved the shutdown millions of Pounds, but he's not getting any recognition really for that. And he's stuck with now no budget left to do any more*" (CS3–I5). Concerns about job security were also identified in terms of inspection engineers being replaced and businesses that have "*vested interests in maintaining the* status quo *as they benefit from the way things are*" (CS3–I8: decision maker). Fear of technology failure was briefly mentioned in relation to concerns that should NII fail to detect an anomaly the consequences could be disastrous.

NII offers a range of benefits including considerable financial savings, lower maintenance costs, increased equipment availability, and reducing lost and deferred production time. In addition, it means that there are fewer confined space entries, significantly reducing personal safety risks. One of the publicly available industry documents characterised it as "*any technique that allows vessel internal condition to be inspected or otherwise assessed without requiring anyone to enter has clear advantages with respect to reduced downtime, more frequent assessment and improved safety*" (Lockheed Martin, 2016). However, these appear to be offset by the costs/risks associated with using it. *"NII can be more expensive to actually do. But it's because it's the savings that you get from avoiding shutdown that make it cost effective"* (CS3–I5: developer). Yet these savings are not typically seen in the short term as discussed above. The potential consequences of integrity loss can be huge in terms of process safety, personal safety, and financial repercussions. As one decision maker noted "*the consequences of getting some of the things that we do to manage risk, the consequences of getting some of those wrong are disastrous. When you consider that, maybe we're prudent to have hesitancy*" (CS3–I6). Consequently, there is a high perception of risk and responsibility involved in asset integrity, that engineers (both as gatekeepers and decision makers) are fully aware of when making inspection decisions.

In terms of the risk perception associated with probability of detection of degradation (e.g., corrosion on metal tanks), it appears from the evidence available that in some instances this may be erroneous. For example, assuming competence of both NII technicians and inspection engineers, an NII method may provide a probability of detection at approximately 90–95% (OGTC & ABB, 2018) whereas a human conducting IVI may provide a probability of detection of between 58 and 67% (HSE, 2008). However, this does not appear to reflect the current risk perception of gatekeepers and decision makers as *"intrusive inspection is not the gold standard, but everybody thinks it is"* (CS3–I2: industry technology advisor).

For both NII and IVI, a high level of technical knowledge is required to determine which method is appropriate, to conduct the inspection to a high level of competence and accuracy, and to interpret the results in order to make the correct subsequent decisions. Engineers acting as gatekeepers and decision makers require a high level of knowledge and experience to accurately assess the relative advantages of NII within a specific context however, "*people are getting involved in decision making in all these sorts of areas are not necessarily the most competent and knowledgeable people on integrity and inspection issues*" (CS3–I11: decision maker). Furthermore, interviewees highlighted concerns around a lack of expertise on both the developer and decision maker fronts. "*We need to demystify what goes on in inspection. Not so that senior managers know every step, but so they have an understanding of how this works and what they need"* (CS3–I2: industry technology advisor).

These concerns may be partly influenced by perceptions of uncertainty and negative previous experiences. Several interviewees discussed examples in which degradation was missed by the service provider and only retrospectively, after an incident, was the issue identified through further analysis - *"that's massively embarrassing to have a through wall defect on a defect shutting us down"* (CS3–I11: decision maker). It is likely that these poor previous experiences would be disseminated amongst professional peer groups (see social influences below), influencing gatekeepers' technology attitudes and risk perceptions. "*Like a lot of the solutions in our industry, there's no real root cause that's fed back to the masses. You just hear "it didn't work for [an operating company]." "Oh no, didn't work for [an operating company] should we be doing it?" Why didn't it work for [them]? So, yeah, it's anecdotal evidence*" (CS3–I2: industry technology advisor). However, it was noted that this was also the case for internal inspections *"where people have just not inspected things properly"* (CS3–I9: decision maker).

Several stakeholder groups are involved in NII including industry bodies, the regulator, service companies who provide NII, service companies who provide IVI, and operators who use a mix of inspection methods. With so many groups involved, it is unsurprising that social influences were identified and that *"two sides of the camp"* (CS3–I9: decision maker) were distinguished – those who use NII extensively and those who do not. This professional network has influenced the introduction of NII both positively and negatively. Social influences were also identified at a broader industry level which was described as *"a sort of herd instinct there. If everybody's doing it, we'll do it. If nobody's doing it, we're not starting first"* (CS3–I7: developer). Conducting IVI appeared to be the subjective norm of *"we've always done it this way"* (CS3–I7: developer) and common practice (see organisational factors).

Both the NII technology developers and decision makers within adopting organisations recognised the impact that product champions could have on technology uptake. Developers perceived these champions as able to see the bigger picture and recognize that there would be "a *benefit to the business overall"* (CS3–I4: developer), assigning them power to be able to facilitate uptake within an organisation and across the industry. Being supportive of the technology was not sufficient to support positive technology decisions, champions had "to have the authority to be listened to and take actions" (CS3–I5: developer). In some instances the champions could act as gatekeepers, operating as a "*matchmaker – I knew that [operating company] had an appetite internally to do something so I set up some meetings and it went from there*" (CS3-2: industry technology advisor). It was acknowledged that without these product champions who had buy-in and were driving the uptake of NII, *"it's very difficult to overcome that inertia"* (CS3–I6: decision maker). In one adopting organisation, the role of the champion was integrated into their adoption process of NII, including being accountable for the technology. "*There are designated and nominated people with just such responsibilities within each building so if I go and click on any of the level two [inspection] procedures that we've got, it has a review date, and somebody is the owner -somebody is the originator*" (CS3–I6: decision maker).

Organisational norms and procedures around NII, inspection budgets, differences amongst departments within an organisation, and taking a short-term view of the financial benefits of NII were found to act as barriers to adoption. "*A conservative culture that has some resistance to change is not unexpected*" (CS3–I8: decision maker). However, champions and decision makers *"taking ownership of the work and sometimes challenging the decisions"* (CS3–I3: decision maker) was a way of changing the technology adoption culture around NII. Reversing organisational procedures and norms around NII by requiring justification for IVI rather than NII, was found to make a significant change. *"It's a simple change, but I think it did change behaviours quite dramatically"* (CS3–I6: decision maker). By embedding NII into normal working practices, it has changed the organisational culture towards it. Having a holistic culture of the benefits that NII can offer combined with a long-term vision of the business was valuable. It was suggested that developing a collaborative culture may help organisations share their experiences, lessons learnt and develop the required technical knowledge for effective deployment of NII across the industry. Leadership and support from senior management is a fundamental component of successfully introducing NII. These senior figures were described as buying into the benefits that NII offers the business and therefore to *"push it out"* (CS3–I1: industry technology advisor), rather than the asset inspection team having to sell it. Senior managers who send out messages around the potential value of NII can change priorities and decision making around it. *"This can really get the momentum going"* (CS3–I4: developer). Organisational incentives are a key motivator for behaviours and decision making. It was perceived that service companies, operators and integrity teams are not incentivised to try new technologies out (e.g., budgetary constraints). Yet, there appears to be a proportion of senior leadership that are either not fully aware of NII or do not directly support it, and *"without that support, we may struggle"* (CS3–I2: industry technology advisor).

5.4. Case study results summary

The analysis of the case study data (interview data, observations, and document analysis) identified six psychological categories and 15 factors as shown in Table 4. These factors were identified as influencing technology adoption decisions of key gatekeepers and decision makers (e.g., operational and technical managers) within the three case studies in the UKCS O&G industry. These data reflect the psychological factors identified within the technology adoption literature and the barriers highlighted in the O&G industry (Wood, 2014), supporting the P-TAF. Whilst not intended to test or refine prominent technology acceptance models, the results do reflect the factors identified across these models (e.g. TAM, Venkatesh and Davis, 2000; organisational technology adoption models, Frambach and Schillewaert, 2002). Having a more comprehensive psychological framework may also be useful to inform these models and subsequent implications for practitioners. Given that decision makers represented half the sample, the interview data were examined to determine if decision makers and developers mentioned different factors. The pattern of results did not indicate any clear differences but further research with a larger sample size may be able to determine if the two groups (developers and decision makers) perceive there to be different psychological barriers to technology uptake.

Several psychological factors were identified as central influences across the three case studies such as the positive or negative technology attitudes and trust.

5.4.1. Within case results

The results signalled that the impact of the psychological factors on gatekeepers and decision makers may vary depending on the context. Case study 1 characterised a start-up company which had a technology that was in the process of being trialled. The results indicate that personal incentives of gatekeepers and decision makers, developing a sense of trust with prospective clients and decision makers, and managing risk perceptions of the gatekeepers and decision makers in relation to the technologies application, were particularly relevant. In addition, the developers perceived social influences, in particular the impact that product champions (and product snipers) could have on the successful outcome of their technology. To a lesser extent, the developers and decision makers highlighted the effect that the technology adoption culture could have on the gatekeepers and decision makers decisions.

Case 2 characterised a start-up company which had now reached commercialisation holding several contracts with tier 1 operators. The results suggest that the risk perceptions of gatekeepers and decision makers were particularly relevant, impacting on the success of the two technologies (SubseaT and DownholeT). This appears to have been affected by the technical knowledge of decision makers and champions. In this case, product champions were found to be highly relevant, influencing technology attitudes, risk perception, and social influences. They provided access to key gatekeepers as well as influencing the wider technology adoption culture of the organisation in which they work.

Case 3 characterised a set of NII technologies that despite being well established continued to be resisted by industry. The results suggest that a combination of a lack of personal incentives, risk perceptions associated with traditional internal visual inspection and non-intrusive inspection, and a mixture of technical knowledge about the relative risks and benefits of the technologies were particularly relevant. The case exemplified the impact that social influences can have on uptake with clear social groups (IVI supporters and NII supporters). Leadership endorsement was perceived to be instrumental in facilitating positive technology adoption decisions, influencing gatekeepers' and decision makers' technology attitudes and risk perceptions. The wider technology adoption culture, including how managers incentivised NII, influenced attitudes, social influences, and risk perceptions.

Within the first two cases, it would appear that developers placed significant value on the positive (or negative) influence of product champions. This was similar within case 3 but in this instance both the developers and decision makers recognised the value that product champions can have on facilitating uptake not only within an individual organisation but the wider industry.

5.4.2. Across case results

Across the cases, technology attitudes were identified as driving technology uptake. Positive technology attitudes in which innovation was valuable for its impact on individual and overall business performance, tended to support positive technology uptake decisions. On the other hand, negative technology attitudes in which stakeholders preferred the status quo, resulted in a lower appetite for technological change. It would appear that decision makers tended to hold more positive attitudes about technologies that they perceived to be less radical (e.g. case study 2).

Personal incentives acted as strong motivating factors, influencing attitudes, risk perceptions and technology behaviours. Personal incentives included concerns about job security, conflicts with similar projects/technologies, and personal agendas, all influenced uptake decisions. The results from case study 3 also indicated that the individual who makes the decision, may not be the one that benefits from it, demotivating the desire for change. Motivations may also be influenced by whether the benefit is gained quickly in the short-term or slowly in the longer term.

Technology decisions heavily focused on risk perception and these judgements required the technical knowledge to make accurate risk assessments. The results indicate that risk perception is linked to not only the technology but the context that it is used in (e.g. in case study 1 the same technology was more readily deployed in a context which was perceived to be less risky). This is unsurprising given the hazardous environments present in the O&G, but it may be valuable to consider not only the risk associated with the technology but the social and environmental context in which it is deployed. Negative previous experiences of introducing new technology influenced technology attitudes, trust, and risk perception, even when it was not a closely comparable technology being deployed. These experiences may prime technology adoption decisions.

The results suggest that irrespective of technology type or readiness level, social factors (such as developing strong professional networks within the technical areas, in different types of organisations, and across industry), were key facilitators. From both the start-up and decision maker in an organisation's perspective, it was valuable to attend events (e.g. conferences, seminars, and accelerator programs) and get involved in the innovation space not only to build a strong professional network but to learn about the latest technologies and their potential applications. The results also suggested that social influence could be used to the advantage of an individual or company attempting to introduce a technology. By having multiple stakeholders involved, it reduced risk perceptions and projected these organisations' credibility onto the technology (i.e., if they are using it, it must be good).

Organisational cultures which recognize the value that technology can offer, promote positive subjective norms around technology and senior management that prioritized innovation, as well as learning from these innovation experiences, tended to respond more positively. Leadership was identified as critical for successful technology uptake, signalling innovations value and the organisation's priorities through their communications, backed up by resources (personnel time and financial). A full cross-case discussion is given in the Discussion section.

Within individual case studies there were factors which were not identified (e.g., collaboration culture in case study 2) or minimally identified across the three case studies (e.g., risk aversion). It may be that interviewees felt that they were not relevant, were of sensitive nature, were too obvious, or the underlying essence was captured by other sub-factors. In some instances, it may be that broader sub-factors may better capture the influencing factors. Whilst the researchers were keen to remain open to new themes, no additional psychological categories or factors were identified.

6. Discussion

People are a fundamental part of successful technological innovation. Without the support of the influential gatekeepers, it is unlikely that a novel technology will be introduced to an organisation, which can result in significant financial losses if the product proves to be successful. Consequently, understanding the psychological factors that impact upon the adoption process is crucial to ensure that the potential of innovation is maximized. The case studies illustrate the cutting-edge technology which continues to be developed in O&G and that lies just beneath the surface of the industries' conservative reputation. The results bring to the fore the sometimes-hidden psychological facilitators and barriers that influence technology adoption decisions in O&G. Insight into these influencing factors can be utilized to support effective technology uptake directly within O&G but also indirectly in other sectors which are experiencing a combination of digitalisation and resistance to technology (Nambisan et al., 2019).

6.1. Psychological technology adoption framework

Our case studies provided further evidence to support the set of 15 factors in the new Psychological Technology Adoption Framework (P-TAF) developed for upstream oil and gas, as shown in Table 4. The psychological factors identified within the case studies can all be separately found within prominent models of adoption at the individual (e.g. Venkatesh et al., 2003), group (e.g. Hughes et al., 2018) and organisational level (e.g. Frambach and Schillewaert, 2002), indicating that these are underlying determining factors for technology adoption decisions. For example, risk, trust, and social influence have been found to impact on technology introduction in a range of industries such as e-commerce (Pavlou, 2003), food manufacturing (Makkonen et al., 2016) and autonomous vehicle driving (Endsley, 2017). Despite the inclusion of some of these factors in dominant models, this is the first comprehensive framework that outlines the key psychological factors that influence corporate consumers within the organisational context. Our case studies add to this nascent research area by providing empirical support for the set of factors included in the P-TAF.

The role of technological gatekeepers is well recognised within the innovation literature (Allen and Cohen, 1969; Nochur and Allen, 1992) and has been studied in a range of domains (e.g., medicine; Carlsen and Norheim, 2003) but less so in oil and gas (Cullen, 2011). The results emphasize the critical role that gatekeepers and champions play in facilitating or blocking technology adoption within upstream O&G. In this context, gatekeepers and champions were typically technical or operational managers who understood the technical area and the problem that they technology was addressing, with budget holders being perceived to hold considerable decision-making power. They could also include industry advisors, senior management in current or potential client organisations or opinion leaders. Whilst both developers and decision makers recognize the impact that people within these roles can have, the results suggest that this power is more keenly felt by developers who are at an earlier-stage of development and deployment. It may be that more established companies have wider social networks, stronger reputation, and credibility so they feel less at the mercy of gatekeepers and snipers/champions. The case study results indicate that decision makers are influenced by a range of psychological factors, in particular their technology attitudes, personal incentives, risk perception and technical knowledge. These factors also appear to interact with social influences (e.g., having attitudes informed by others in a social network), particularly product champions. Given that gatekeepers are not always formal/explicit or observable, they may be able to wield a greater influence than is commonly attributed to them (e.g., ignoring a pitch request or being unwilling to pass on details to a relevant colleague). The interview results suggest that product champions are well recognised for the positive impact that they can make but that gatekeepers and decision makers are less well understood. Consequently, it is pertinent to understand the psychological factors that influence these essential individuals.

The following sections will briefly discuss the overarching psychological categories, highlighting the main facilitating factors and potential barriers.

6.1.1. Personality factors

From the individual corporate decision maker's perspective, innovativeness was found to be influential, (Perrons et al., 2018; Tabak and Barr, 1999), particularly the innovativeness of leaders and product champions. This factor appears to be similar to domain-specific innovativeness (Goldsmith and Hofacker, 1991) and technological innovativeness (Thakur et al., 2016). Examination of how innovativeness influences technology adoption decisions may be valuable as a future research avenue (e.g. as a selection tool), with a similar approach applied to procurement (Steenstra et al., 2020). Risk aversion which had previously been identified as a relevant factor (Oyovwevto, 2014; OGTC and ABB, 2018) was not frequently mentioned within the case studies. However, in the case in which it was mentioned, the technology was perceived to be radical. This supports the idea that risk aversion may be intensified for radical technologies (Assink, 2006; Radnejad and Vredenburg, 2019).

6.1.2. Attitude factors

Factors such as personal incentives, previous experiences, information gathered through social networks and risk perception as well as organisational norms influence technology attitudes. A cross section of attitudes were identified in the case studies. The perceived value a technology may offer to the way the individual worked, to the business and/or to the industry overall was balanced against skepticism and poor previous experiences of technologies. Trust was identified as a critical attitudinal facilitator in the introduction of new technology in O&G particularly in uncertain or risky situations (Kaur and Rampersad, 2018; Pavlou, 2003). In particular, it was identified as crucial for start-ups to develop a sense of trust between them and their clients, not only around the individual contact but with the wider company and technology. One method of increasing perceptions of credibility, trust and familiarity was to use product champions. These are individuals who are well respected within their domain, use the right language to sell the product and see the potential value/impact of that it could have, and who use their extensive network to 'sell' the product to other network contacts (Markham and Aiman-Smith, 2001).

6.1.3. Motivation factors

Personal incentives and fear of technology failure acted as strong motivating factors, influencing attitudes, risk perceptions, and technology behaviours. In terms of innovative individuals, motivation to introduce new technology may be intrinsic (i.e. they do it because they enjoy the activity of introducing and using new technology). However, the results suggest that these may be extrinsic motivational factors (i.e., they do it because of external sources such as organisational pressures) (Herath, 2010). Personal incentives focused on concerns over job security, budgets, and clashes with internal projects which may conflict with the new technologies. Organisational culture would likely also influence motivations through norms, priorities (e.g., cost cutting) and strategies (e.g., the way in which departmental budgets are governed). The role of motivation on technology adoption is unsurprising given that it has been identified as a central factor for technology adoption behaviours in other sectors (e.g., agriculture (Herath, 2010), e-commerce (Abu Bakar and Ahmed, 2015) and online security (Chenoweth et al., 2009). Practitioners involved in technology adoption would be wise to consider the underlying motivations that drive clients', managers', and end-users' behaviours.

6.1.4. Cognitive factors

The perceived risks associated with introducing a technology was identified as a psychological factor for technology decisions in all three cases. This reflects the wider innovation literature (Ghadim et al., 2005; Paluch and Wünderlich, 2016) and illustrates to start-ups the value of framing risk, value proposition and motivations. Risk judgments are closely linked to perceptions of certainty, memories of (positive or negative) previous experiences with introducing new technologies, and the level of technical knowledge that the decision maker holds (Barham et al., 2014; Ghadim et al., 2005). Technical knowledge and expertise are crucial for accurate risk assessments when introducing an innovation into a system (Damanpour et al., 2018). Several interviewees noted that lack of technical knowledge erroneously increased risk perceptions of prospective clients who did not fully understand the purpose, value, or potential broader implications of the technology for their business. The outsourcing of knowledge and reductions of workforce, seen in many industries, has shifted the locus of knowledge in some instances away from the decision maker (Perrons, 2014).

6.1.5. Social factors

Social factors such as professional peer networks and subjective norms were found to influence technology adoption decisions and behaviours. Individuals would seek validation about a potential technology from others in their network (e.g. have they heard of the technology, was it valuable, and would they recommend it?). Utilising social networks was highly valuable for start-ups who lacked trustworthiness. Recruiting product champions was a way of overcoming limited social networks, gaining credibility, and access to potential clients. In the wider context social factors such as social influence and word of mouth have already been found to influence rejection decisions in late adopters (Jahanmir and Cavadas, 2018), such as those characterised by the O&G industry. This may be relevant for those involved in technology adoption practices within late adoption organisations and industries.

6.1.6. Organisational factors

Organisational cultures which recognize the value that technology can offer, promote positive subjective norms around technology and senior management that prioritized innovation, as well as learning from these innovation experiences, tended to respond more positively to innovation (Daneshy and Bahorich, 2005). In contrast, organisational cultures that were characterised by a short-term approach and were perceived to have a pervasive fear of technology failure, stifled innovation and tended to stick with the status quo. As innovation typically adds value through long-term gains, this may be in contrast with the perceived competitive short-term O&G industry culture (Hirsch et al., 2005). Given that much of the technological advancement in O&G, as well as for many sectors experiencing digitalisation, hinges on collaboration and sharing of information, having a collaborative culture which is willing to share non-critical resources and has a high absorptive capacity could increase the receptivity to innovative and new ways of working (Radnejad and Vredenburg, 2017). Tentative steps to supporting collaboration have already been taken such as through open innovation (Radnejad and Vredenburg, 2017) and strategic dalliances (Noke et al., 2008). Consequently, being able to improve technology adoption cultures could be highly valuable through measurement and benchmarking exercises.

6.2. Case comparisons

Across all three case studies almost all the psychological factors were identified demonstrating that they are important, irrespective of context. However, the results also indicated that specific factors may particularly influence technology adoption decisions in specific contexts. The involvement of innovative individuals and product champions were particularly relevant for companies that were seeking validation trials for unproven technologies or at the early stages of commercialisation. For very early-stage technologies, such as that outlined in case study 1, identifying and gaining access to the relevant expertise to assess the potential risks, benefits and applications was important. Where individuals and/or technologies were unproven, developing a sense of credibility and trust with clients was crucial for winning funding for trials or early stages of commercialisation. For technologies that were well-established but continued to be resisted, organisational culture was identified as a key facilitator. Organisations which fostered a positive technology adoption culture, combined with innovative individuals and leadership support, tended to be more responsive to trying innovative technologies. Where leadership was not present, technology uptake was sluggish. Overall, the case study results emphasize the point that it is not sufficient to have a technically competent technology but that it must also be presented in a way that encourages decision makers, end-users and organisations to become receptive to it.

6.3. Industrial context

In comparison with oil and gas, similar psychological factors have been identified in other industries such as risk aversion (e.g. defence; Greiner and Franza, 2003), technology attitudes (e.g. IT Systems; Davis et al., 1989; automated driving; Ghazizadeh et al., 2012) and organisational culture (e.g. IT systems, Frambach and Schillewaert (2002); and manufacturing (Kratzer et al., 2017). However, given the high risk, high reliability nature of the oil and gas industry, risk perception and technical knowledge were identified as prominent variables, as well as how leaders manage technology adoption cultures.

The O&G industry may be perceived as facing a unique problem; however, they appear to share many characteristics with other industries. Examples include the high risk, high reliability nature (e.g. healthcare), financial implications of failure (e.g. banking), automation (e.g. motor manufacturing), increasing governmental focus on the environmental impact (e.g. aviation) and decommissioning (e.g. nuclear power). Furthermore, they are not the only industry to have a reputation for being resistive to adopt new technology (e.g. healthcare; Williams and Dickinson, 2010) but need it to remain competitive. It is likely that many more sectors will experience the paradox between embracing technology and the resistance to innovation as a result of introducing digitalisation, as well as the adoption of new technologies in response to the Covid-19 pandemic (Clipper, 2020; Juergensen et al., 2020). Consequently, those working to introduce innovation in industries outside of O&G may recognize similarities in the case study results and may find that the P-TAF is valuable for better understanding, and effectively implementing, technology into their own organisation.

Research looking at the energy efficiency paradox may illustrate similarities to the psychological factors identified as impacting on technology adoption decision making. The energy efficiency gap represents companies' resistance to uptake energy efficient technologies, despite their relative advantages and cost savings. Similar adoption barriers to those identified within O&G have been highlighted in the construction industry such as industry culture, no long-term incentive or interest in a project, competitive tendering, and poor collaboration between stakeholders (Sorrell, 2003). It has been posited that a combination of market and behavioural barriers (e.g. salience, inattention, heuristics decision making, and loss aversion) may reduce uptake of energy efficient technologies across sectors (Gerarden et al., 2017). Psychological/behavioural barriers such as perceived risks, motivations, cognitive resources, and preference for the status quo, have been found to contribute to slow investment in green technologies (Knobloch and Mercure, 2016). Given the increasing need to invest in green, energy efficient technologies as part of the climate crisis and the energy transition, it is expected that these psychological and behavioural factors will become increasing pertinent.

6.4. Limitations & future research

The case studies add to the literature by confirming the comprehensive set of the psychological factors that can impact on technology adoption in O&G, however there are methodological limitations. Interviews provide self-reported data and can be subject to bias, as well as motivational agendas (Rowley, 2012). These motivational agendas may have been present within the sample (e.g. motivations from technology providers to convey a particular narrative around their innovation). To support content validity, the sample was selected with participants from different organisations, roles, and perspectives within the UK continental shelf (UKCS). This included interviewing those outside the technology companies (e.g. current and/or prospective clients, industry experts) to get a wider perspective. Initially this posed a challenge as individuals from the technology developer companies were reluctant to share contact information and were concerned that asking their potential clients to take part in the study could jeopardize future business. Whilst their concerns were alleviated and potential decision makers from client organisations were interviewed, further research would benefit from gathering a wider decision-making sample (e.g., senior managers and budget holders in potential client organisations).

The addition of observational data and document analysis while on a small scale, supplemented the interview material. The document analysis was beneficial for providing additional contextual information which assisted in the identification of psychological factors. However, alternative samples from other basins (e.g., Gulf of Mexico) or other industries within the energy sector (e.g. offshore renewables or nuclear power) may have identified alternative psychological factors as influencing technology uptake decisions. This expresses the wider issue of external validity and generalizability of qualitative research. Furthermore, despite attempts to collect a larger sample of cases, only three were examined. We would invite researchers to apply the framework to case studies examining technology adoption in other sectors such as business, healthcare, and IT systems.

The types of technologies examined within the case studies may also reduce the generalizability of the findings. For example, cases 1 and 2 focused on tangible, physical technologies that could be handled by prospective clients. Whilst case 3's technology includes a combination of physical hardware and analysis software; the psychological factors that influence uptake of digital technologies may vary from physical technologies (e.g. Adjekum et al., 2018). Given the uptake of digital technologies as part of digitalisation, this may be a valuable avenue for further research not only for application in O&G but in healthcare, manufacturing, and business.

Whilst examining demographic characteristics (e.g., age, income, educational level) was outwith the scope of the study, it is possible that these may have influenced technology adoption decisions, as has been found for age effects in consumer technology acceptance (Arning and Ziefle, 2007), leaving a potential route for future research.

As for many models, the psychological factors appear to be interrelated, overlapping with each other (e.g., innovativeness may influence risk perception and technology attitudes). To address the issue of circularity of reasoning, the authors remained open to any additional psychological factors which may influence technology decisions within the case studies. It should be noted that additional non-psychological factors (environmental factors) were mentioned but not included as they were out with the research scope. Furthermore, the addition of the non-psychologist authors who did not have strong preconceptions about these factors was valuable for a rigorous discussion of the results. However, the coding analysis was based on a preliminary framework (P-TAF) devised by the authors and although the method was designed to identify any additional factors, it would be beneficial to have the set of 15 factors tested by an independent investigation, particularly the categorisation and labelling of the factors. It is possible that different factors influence individual consumers and corporate consumers differently (e.g., a corporate consumer may be influenced by organisational culture) but is also feasible that O&G terminology refers to these underlying factors using different terms (e.g. relative advantage may be included within risk perception). This may be a valuable route for further investigation. Ongoing research will seek to quantitatively test this model by building the key factors into a predictive model which will allow the influence that these factors have on technology adoption decisions to be tested.

Given the value that Roger's DOI model (2003) has provided for the innovation literature and that practitioners are familiar with it, further research could apply these psychological factors to the 5 stages of diffusion as it is likely that their impact will differ. This approach could be valuable for developing stage-specific interventions.

6.5. Practical implications

There are several potential routes for supporting technology adoption by leveraging the influence of psychological factors identified within the case studies from both the buyer and seller perspective. The results suggest that sellers (e.g., technology developers and service companies) and buyers (e.g., customer organisations wishing to introduce a technology) may face different psychological barriers when trying to adopt a technology. Within the case material on the psychological factors, there were examples given relating to best practices and these are summarised Appendix B. Further examination of these psychological factors is required to provide robust recommendations, however preliminary suggestions are outlined below to give the reader indications on how they may facilitate technology uptake in their own organisations.

Both technologies and their parent companies can be at different developmental stages and, as a consequence, may face different psychological barriers. The case studies suggest that from a start-up perspective, psychological factors such as trust, product champions and gaining access to expertise appear to be pertinent. Given that securing funding and access for field trials can be a complex process for even the most experienced individuals, start-up companies may find value in a guide which outlines how to jump these psychological barriers.

Whilst there is a considerable research base on organisational culture for innovation (Frambach and Schillewaert, 2002; Radnejad and Vredenburg, 2017), there does not appear to be an empirically based measure for an organisation's technology adoption culture in O&G. Recent research has highlighted the need for organisations' cultures to be receptive to new ways of working and technology (Lokuge et al., 2019; Webster and Gardner, 2019), therefore developing an organisational technology adoption culture may be valuable for supporting technology uptake (e.g., for benchmarking technology adoption culture activities (Radnejad and Vredenburg 2017; Pak et al., 2019).

7. Conclusion

Technology advancement is vital for the future of not only the oil and gas industry but a sustainable energy supply within our lifetimes. Many people continue to work relentlessly developing technological solutions to these problems; however, their innovations are only successful if they are taken off the proverbial shelf, adopted and used. For a new technology to be successful, it needs to not only be technically competent but presented to potential buyers in a way that organisations, leaders, and end-users are receptive to it. Understanding the psychological factors that drive technology adoption is a key part of that success.

Our case study research addresses this challenge by confirming the key psychological factors (in P-TAF) that influence corporate technology adoption decision makers within the upstream oil and gas industry. Whilst the factors can all be separately found within prominent models of technology adoption, there was not a comprehensive framework that outlines the key psychological factors influencing corporate consumers within the organisational context. Given the potential benefits of digitalisation, understanding the organisational innovation adoption process, and the psychological factors which influence it, will become increasingly pertinent to technology developers, organisational leaders, and policy makers.

The innovativeness of the decision makers, their technology attitudes, their trust in the technology and its stakeholders, personal incentives and their social network will all influence their decision to introduce a technology (or not). Their risk perception of the innovation will be influenced by their technical knowledge and their previous experiences. The organisational culture in which they work will influence all aspects of their decision-making process, driving motivations, attitudes, and risk perceptions. Most of all, leaders can direct organisational values, resources, and the way that technology adoption is embraced.

The three case studies have provided indications of the psychological facilitators and barriers, which can be studied to inform the design of actionable tools and recommendations. It is hoped that this understanding may be used both by academics to advance knowledge of the innovation process and by practitioners trying to smooth the bumpy road to deployment and adoption. In essence, our study illustrates the power that people hold to make an innovation a success or a failure.

Data availability

Data analysis methods are included in the methods section and the semi-structured interview schedule is in Appendix A, however, to maintain the confidentiality and anonymity of the interviewees, as per our ethical requirements, individual data will not be made available.

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Appendix A. Supplementary data

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