ABERDEEN BUSINESS SCHOOL
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Best practices for the introduction of new technologies: Investigating the psychological dimension

Work Package 1: Literature Review

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Executive Summary

This report describes the findings of the first work package from the OGTC funded research project “Best practices for the introduction of new technologies: Investigating the psychological dimension” being carried out by industrial psychologists from Aberdeen Business School, Robert Gordon University. The two-year project (2018-2020), consists of six work packages.

To maximize the opportunities for the adoption of newly developed products, there is a need to better understand how psychological factors impact on the acceptance and deployment of innovative technology in industry. While there is an extensive general literature on the psychological factors which influence consumer behavior and the use of new technologies, there seemed to be very limited understanding of this topic specifically relating to the upstream energy sector. This project is designed to examine how the particular attributes of the upstream oil and gas industry on the United Kingdom Continental Shelf (UKCS) interact with the underlying psychological processes that govern adoption and deployment decisions.

For work package 1, a literature review was conducted with the aim of identifying: a) what, if any, research has been conducted in relation to the psychological factors influencing technology adoption and deployment in the oil and gas (O&G) industry; b) what interventions have been developed to support technology adoption in O&G. Following an extensive literature search, 17 papers which examined psychological factors that influence technology adoption in O&G were identified. Thematic analysis of these studies was conducted to identify the key psychological factors that impact on technology adoption.

A common message within these papers was that there is a continuing need for this sector to harness the potential of technology innovation and support adoption, yet only five psychological factors were identified. These were personality (e.g. exploration traits and risk aversion), attitudes (e.g. trust and not invented here syndrome), social (e.g. social norms), cognition (e.g. risk perception), and psychological factors at an organizational level (leadership and organizational culture). Our review identified a small number of interventions developed and deployed to support technology adoption in O&G. However, these typically did not address the underlying psychological factors, such as attitudes, motivations or leadership, which will likely influence subsequent innovation deployment and adoption.

The review confirmed that there has been very little research to identify the psychological factors that impact on technology adoption in O&G, therefore a number of knowledge gaps remain. These include: establishing whether psychological factors known to be relevant to technology adoption more generally, apply in this industry; determining how the specific characteristics of the O&G industry interact with the psychological factors; and developing empirically based interventions that can navigate the psychological barriers to technology adoption in O&G. The subsequent work packages aim to address these gaps through interviews (work package 2) and case studies (work package 3). Key learnings from the health and safety journey may be valuable to draw on for the current challenge of technology adoption. Based on the findings, the final stage of this research project will develop and evaluate a tool set, relating to the psychological factors, to support successful deployment and adoption of innovative technology.

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1. Introduction

Innovation is the foundation on which the oil and gas industry was built and is critical to the future success of the business (Longwell, 2002; Perrons et al., 2014/2012; Wood Review, 2014)). This report describes the findings of the first work package from the research project "Best practices for the introduction of new technologies: Investigating the psychological dimension" being carried out by industrial psychologists from Aberdeen Business School, Robert Gordon University. It is part of a two-year study (2018-2020), sponsored by the Oil and Gas Technology Centre (OGTC), consisting of six work packages.

The value and benefits of innovation are becoming ever more relevant given the challenges that the industry is facing. Much of the "easy oil" has already been consumed, requiring greater technological innovation to tackle more complex, deeper wells to maintain future O&G resources (Paul, 2007; Perrons, 2014). In addition, the UKCS has an additional challenge of stranded assets (commonly referred to as small pools) which given their size and location make it financially, rather than technically, difficult to exploit. The need to automate high risk, error prone tasks, as well as the future challenges of decommissioning highlight the necessity for technological innovation (Hassani et al, 2017).

Despite these motivating factors, the road to deployment and adoption of new technological innovations is not as smooth as might be anticipated. The industry has a reputation for being conservative and reluctant to adopt new technology (Perrons, 2014; Wood Review, 2014), the companies are often referred to as "fast followers" (Daneshy & Donnelly, 2004). Compared to other sectors, O&G has a set of unique characteristics that can hinder technology adoption. The shared equity structure can result in innovations being shared with partners who have not invested in the technology, resulting in the competitive advantage that an innovation may have otherwise offered becoming eroded. This economic problem is commonly referred to as "free ridership" (Perrons, 2014). Furthermore, the sector is characterized by its "slow clock speed" in which the uptake of new technology can average 16 years to have widespread industry adoption (Noke, Perrons, & Hughes, 2008; NPC, 2007; Weijermars, 2009). These characteristics have the potential to create a hostile environment for the adoption and deployment of new technology, negatively impacting on the future growth of the industry.

Whilst there are significant efforts to support and improve adoption of technology innovation in the O&G sector, there is a need to understand the underlying factors that influence this process. Research in other industries indicates that there are a range of sector, organizational and psychological factors that can influence deployment, adoption, and acceptance of technology (Sethna & Blythe, 2016). Evidence from O&G industry bodies indicate that it is these psychological factors that play a key role in technology adoption, but they are less well understood than market or organizational factors. They include risk aversion (Wood Review, 2014), lack of ownership and leadership around technology (OGTC, 2018 data analytics report), with an attitude that is reluctant to change (OGA, 2018). This has the potential to lead to over-cautious technology decisions (OG21, 2018).

As a step towards supporting technology adoption in upstream O&G, this report first outlines in section 2, the key psychological factors identified as impacting on technology adoption from the broader consumer behaviour and human factors literatures. Section 3 gives the aim of this work package, then section 4 reports the method. Section 5 reports the findings of a literature search for specific research studies examining the psychological factors that influence technology adoption in O&G. Section 6 outlines the interventions described in these studies.

Section 7 discusses the psychological factors that appear to influence O&G technology adoption.

2. Technology Adoption Research

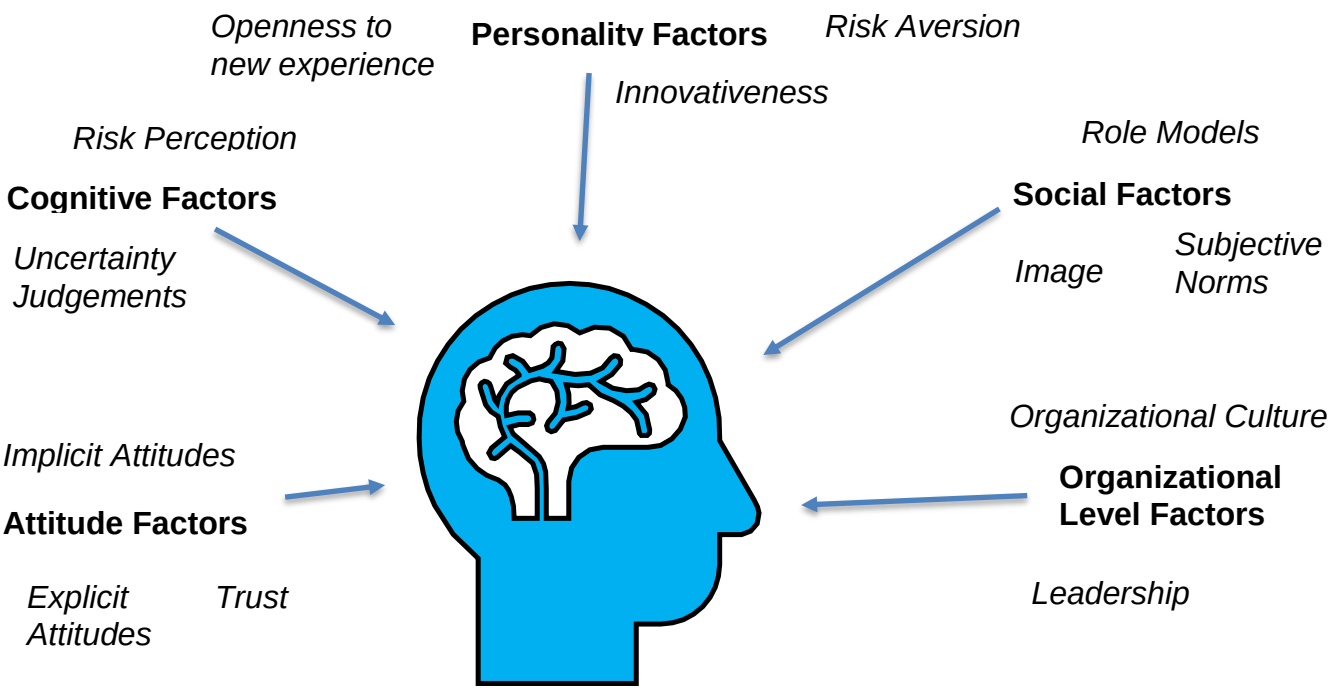
An innovation is an idea, a product, a program or a technology that is new to the adopting unit (Rogers & Shoemaker, 1971): Adoption of that innovation simply relates to the decision to make full use of it (Rogers, 1995).The process of innovation adoption is widely recognised as a three-stage process of initiation, adoption-decision, and implementation (Rogers, 1995; Pichlak, 2016), although some differences are evident in the literature (see Oorschot, Hofman, & Halman, 2018). More recently, researchers have discussed adoption in terms of seven stages of assimilation (awareness, interest, evaluation, commitment, limited deployment, partial deployment and general deployment) in which the adopters are active participants in the process (for a full, in-depth discussion, see Hameed et al., 2012a and Makkonen et al, 2016). A key component of these stages of assimilation and adoption is the formation of attitudes towards both the innovation and the proposal of adopting it. These attitudes impact on decision making processes and subsequent adoption behaviors (Rogers, 1995).

It can be valuable to consider how people, companies and potential clients fit into the technology adoption life cycle. The model categorizes the adopter groups as based upon demographic and psychological characteristics (Rogers, 1983). Innovators are the first to use a new product, closely followed by early adopters and then the early majority, late majority and laggards.

There is no universally accepted model of innovation adoption, with a range of models being utilized by researchers to examine adopter attitudes, behaviors and the influencing factors that can impact upon this process (see van Oorschot, Hofman, & Halman, 2018). The key models relevant to technology innovation adoption, from both the end-user and organizational approach, were identified (See Appendix A) and used to pinpoint the underlying psychological factors, that drive subsequent innovation adoption behavior.

The main psychological factors are shown below in Figure 1 and a brief summary of the personality, cognitive, attitude, social and organizational aspects is now given. For more detailed explanations of these psychological constructs applied to new products and services, see Joachim et al (2016) on psychological barriers, Roupas (2008) on entrepreneurial factors, Sethna and Blythe (2016) on consumer behavior and Endsley (2017) on human factors.

Figure 1. Psychological factors that impact on the introduction of new technologies with sub-factors in italics.



2.1 Personality Factors

Personality refers to individual differences in characteristic patterns of thinking, feeling and behaving. Several personality traits are relevant to adoption and deployment of new technology. Individuals are active participants in the adoption process and who possess a level of innovativeness – this is the degree to which an individual is willing to adopt innovations. Various forms of consumer innovativeness have been identified. Innate, personal innovativeness is considered a generalized personality trait whereas domain specific innovativeness (DSI) refers to the tendency to learn about and adopt innovations in a particular topic area (Goldsmith & Hofacker, 1991). The benefit of measuring innovativeness is that it provides the opportunity to target innovators, fostering more efficient diffusion and adoption of new products.

Other personality characteristics, such as openness to experience, conservatism, and cognitive style can also impact on willingness to adopt new technology (Sethna & Blythe, 2016). Personality traits (e.g. introversion) and biodata characteristics (e.g. gender, age) may also be related to risk aversion (Desmoulins-Lebeault, Gajewski, & Meunier, 2018). Risk aversion/avoidance is a personality trait in which there is a preference for a sure outcome over a gamble with higher or equal expected value. This is also related to risk tolerance (i.e. how comfortable a person is with taking a risk).

2.2 Attitude Factors

Attitudes are evaluations that individuals make about people, objects, events or ideas, which can influence subsequent behavior. Attitudes have three components: affective (emotions about the object); conative (influence on behavior and actions towards the object); and cognitive (beliefs and knowledge about the object). An individual will hold beliefs about the results of performing a behaviour (e.g. trying a new device) and whether these results will be pleasant or unpleasant. Typical attitudes to new technologies focus around compatibility,

enhanced use, perceived use and usability. A range of motivations may inform attitudes towards technology adoption at work including concerns about job security, desires to improve job performance, pay or promotion (Davis et al., 1989).

A distinction can be made between explicit attitudes which can easily be expressed and implicit attitudes which may be held at a more subconscious level. Implicit attitudes are formed on an involuntary basis from previous experiences and people are typically unaware of them (Greenwald & Banaji,1995) and they are relevant to new technology as they can influence motivation and adoption behaviors. Implicit attitudes can also manifest as 'passive innovation resistance' (PIR). PIR represents a generic predisposition to resist innovations that have a degree of change of discontinuity as part of adopting the innovation (Heidenreich, Kraemer, & Handrich, 2016). Whereas, Active Innovation Resistance (AIR) is the conscious form of resistance that comes from the functional and psychological barriers that arise after a new product has been assessed (Joachim, Spieth, & Heidenreich, 2018).

Another type of attitude that is relevant for technology adoption and end-user acceptance is trust. Trust is an attitude that we have towards people (or objects) whom we hope will be trustworthy and that they will do what is expected. Trust is regarded as a catalyst for consumer-marketer relationships as it provides the expectations of successful transactions (Pavlou, 2003). However, trust is only required in situations of risk, vulnerability and uncertainty (Lee & See, 2004; see cognition section). For example, trust is important for the successful introduction of automated machines in contexts such as manufacturing, aviation and healthcare (see Endsley, 2017 for a review).

2.3 Social Factors

Social factors refer to thoughts, feeling and behaviours relating to, and caused by other people, including social norms, role models, peer influences, group effects (e.g. status, hierarchies); these can all affect technology adoption. Subjective norms refer to an individual's perception that people who are important to them, think that they should or should not perform a behaviour (Fishbein & Ajzen, 1975), and that these other people (e.g. colleagues, supervisors) have the power to reward that behaviour or punish non-behaviour (see Venkatesh & Davis, 2000). According to the Theory of Reasoned Action (TRA; Fishbein & Ajzen, 1975), it is the combination of attitudes and subjective norms that form the behavioural intention to accept a new technology. Subjective norms can also influence technology acceptance via the motivation to maintain a favourable image within a reference group. In this context, image refers to the degree to which the innovative technology is perceived to either enhance or diminish an individual's social status (Moore & Benbasat, 1991). Role models, peer group pressure and opinion leaders are also likely to impact on image and adoption behaviours in a similar fashion.

2.4 Cognitive Factors

The term cognitive refers to mental processes that drive our knowledge and understanding of the world, including attention, perception, memory, language use and problem solving. Several cognitive factors including risk perception and judgements of uncertainty, memories and decision-making influence technology adoption. Perceptions of uncertainty can arise from different sources (e.g. a fluctuating market, opportunistic behaviour from the seller, or unknown performance of the product), introducing the perception of risk and the need of trust. Risk perception is a subjective judgement of the characteristics and severity of a situation which is influenced by an individual's tolerance of risk (i.e. what they are comfortable with;

Slovic, 1987). Providing additional internal and external sources of information within an organisation adopting a new technology can reduce perceptions of uncertainty and risk, fostering a sense of trust (Damanpour, Sanchez-Henriquez & Hui, 2018).

2.5 Psychological Factors at an Organizational Level

This category refers to the psychological factors that occur at the organizational level including leadership, organizational culture and readiness. The individual attitudes, behaviours and characteristics of the organisational leader or CEO have been identified as imperative for organisational adoption of new technology, such as new IT systems (Damanpour & Schneider, 2006; Pichlak, 2016). This is because leaders are involved in organisational decision-making and their characteristics impact on adoption decision process. Characteristics that have been studied in this context include age, gender, educational level, innovativeness, attitudes, IT/technology knowledge and attitudes towards change (see Hameed et al., 2012 for summary). Organisational culture and readiness can have a significant impact in the way that innovation is either supported or resisted (Frambach & Schillewaert, 2002 and the UTAUT in Table 1). An organization's innovativeness, combined with its strategies, structure, social norms and leadership, will influence how receptive it is towards technology adoption, generating an adoption culture. Given differences in adoption culture, it can also be useful to identify specific organizational adoption behaviors that support technology acceptance, such as the involvement of key individuals and developing solid with peer and technology companies (Makkonen et al, 2016).

3. Study Aim

Given that psychological factors (such as those outlined above) drive key behaviours in technology adoption in other industries, it is important to determine what influence they might have in the oil and gas sector. To examine this question, in work package 1, a literature review was conducted with the following aims: a) to identify what, if any, research has been conducted in relation to the psychological barriers/human factors to technology adoption and deployment in the oil and gas industry; b) to identify what interventions have been developed to support technology adoption in O&G.

4. Method

A literature search was undertaken to identify research studies which had examined psychological factors relating to technology innovation and adoption in the oil and gas industry. Given the limited research anticipated, minimum selection criteria were applied, based upon Cochrane quality control (Higgins & Green, 2011). Details of the search method (including the selection criteria, data sources, and key words) can be found in Appendix B.

Overall, very few studies directly considered the psychological factors that impact on technology adoption. Of the 17 articles that met the search criteria, not all were journal articles, many of them were published over a decade ago and they were typically authored by engineers/ technical specialists rather than social scientists. The most common research methods were either case studies or surveys. The articles were published from 2004 -2018: There is a trend of the older papers discussing the difficulties with adopting new technology

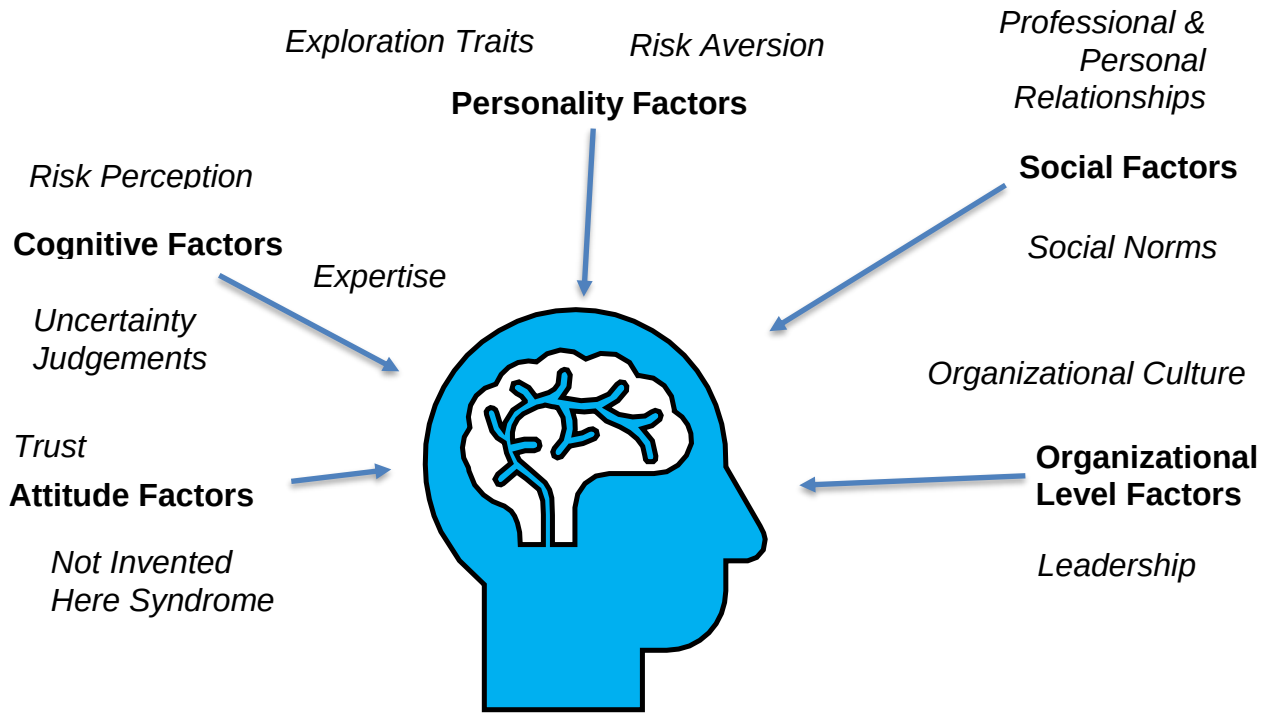
and the more recent papers discussing intervention methods. A summary of the 17 studies, including sector and country of origin, the method and key points, is shown in Appendix C.

The articles were subjected to Braun and Clarke's (2006) thematic analysis, producing a list of the psychological factors that influence technology adoption in O&G.

5. Emerging Themes

From the thematic analysis of the 17 papers, it was clear that very few psychological variables have been examined in studies of factors that influence technology adoption in O&G. Five psychological factors were identified, namely personality, attitude, social, cognitive and organizational level, as shown in Figure 2. The same main categories were identified as in Figure 1, however, there were differences within the sub-categories. For example, additional social factors were identified within the O&G literature (e.g. professional and personal relationships). In addition, four intervention methods were identified, focusing on supporting and fostering collaboration which is known to facilitate technology adoption. A summary of the few extracted themes discussed are outlined below.

Figure 2. Psychological factors that impact on the introduction of new technologies in upstream O&G as identified within the literature review, with sub-factors in italics.



5.1 Personality Factors

A survey of Society of Petroleum Engineers (SPE) members found several biodata characteristics that influence what was referred to as an individual's 'exploration' trait (Perrons, Burgers & Newton, 2018) which was related to searching out new products or evaluating a wide, diverse range of new products. Evidence suggested that this type of personality trait (similar to openness to experience) and associated behaviors support innovation and the uptake of technology through risk-taking, experimentation and discovery (Andriopoulos & Lewis, 2009 in Perrons). The biographical characteristics included having a graduate degree, the country of formative years (up to age 18), the country of employment, and their current role. Those working in R&D were found be the mostly likely to show exploration behaviours, but engineers were the least likely.

Additionally, individual and sector level risk aversion is considered a significant factor in the slow uptake of new technology in O&G (Oyovwevto, 2014). No further details of personality traits were identified in the articles reviewed.

5.2 Attitudes

Trust was found to be an influencing factor in the introduction of automated drilling technology at a Norwegian offshore oil and gas production installation (Saetren & Laumann, 2015). The introduction of the new technology was successful with the crew believing that the change was needed, that this was the right change and that they were able to cope with the change. They believed that their management wanted the best for the crew (see Social Factors), resulting in little resistance to the change. It was suggested that this success was in part due to previous successes of introducing new technology (e.g. introducing new equipment that reduced manual work, was safer and obtained more oil from the reservoir) and that the crew had been engaged early in the development of the procedures as well as being trained on how to use it. This led to the crew trusting and accepting the new technology. However, the authors highlighted that over-trust could result in an over-reliance in the system which could have negative consequences for safety.

The other attitudinal variable which was mentioned was the 'not invented here syndrome' which manifests itself in the form of unwillingness to try new ideas from other companies or locations. This notion that because an innovation was been developed out with the organization, it is consequently poorer was identified as a key attitudinal and cultural barrier for O&G personnel in the Canadian petroleum and petrochemical sector (Radnejad, & Vredenburg, 2017).

5.3 Social Factors

Saetren and Laumann (2015) recognised the importance of the psychological work environment of the offshore O&G industry and how this may impact on end-user acceptance of new technology. For example, close professional and personal relationships amongst drill crew and management created strong social norms and a respectful atmosphere. However, there were also clear social norms about speaking out, conforming to expectations and not disagreeing with management on certain issues. Maintaining these norms were recognized as important for potential promotions. These social factors would likely impact on whether (or not) a new piece of technology was trusted, introduced and accepted.

This article is relevant as it was the both the only article to take an end-user perspective and the only article to identify social factors influencing technology acceptance. This does not

mean that they do not influence technology adoption in the O&G industry but that they were not typically identified within the limited literature available.

5.4 Cognitive Factors

Assessing the potential of innovative technological tools, and judging the associated risks, involves a considerable 'technical backbone' (expertise) within both service and operating companies (Daneshy & Bahorich, 2005). Relevant knowledge and access to additional reliable information sources provide the opportunity to accurately assess the risks and benefits of adopting a new technology. However, there are less opportunities for key decision makers to access available information when making risk/cost judgements about new technologies. For example, reductions in R&D spending and R&D lab closures can lead to poorer understanding of new technologies and the associated risks, contributing to industry risk aversion (Rao & Rodriguez, 2005). No other cognitive factors were discussed in the articles.

5.5 Organizational level Factors

As stated earlier, leadership support for technology adoption is crucial for both the development of and adoption of technological innovations. It was noted in one study that whilst most leaders and senior management in O&G companies are aware of the value of innovation, this was perceived to contrast against their actions that can discourage technology use. This can be seen as part of the strategic cost leadership in which technology is primarily regarded as valuable for short-term exploration activities and to reduce production costs. The term "Corporate Technological Responsibility" was coined more than ten years ago to represent the need for leaders to emphasise the important role of technology for the future success of the O&G sector and take responsibility for technology as part of corporate strategy (Daneshy & Bahorich, 2005).

Creating an organisational culture that supports and accepts technology was identified as a key facilitator (Daneshy & Bahorich, 2005). Incentives and penalties are a key aspect of an organisational culture. Rewarding conservative, short-term cost centric attitudes and behaviours will likely create an organisational culture that does not value technology innovation (Oyovwevto, 2014; Daneshy & Bahorich, 2005; Hirsch et al., 2005). Conversely, organisations which have a high collaborative culture, are willing to share non-critical resources and have a high absorptive capacity are much more likely to be innovative and accepting of new technology (Radnejad, & Vredenburg, 2015, 2017). Absorptive capacity relates to a firm's ability to recognize the value of new information, assimilate it and apply to commercial ends (Cohen & Levinthal, 1990). This capacity for using external information is relevant for stimulating innovation, collaboration and research and design activities, based upon prior knowledge and expertise as well as a diversity of experiences.

6. Interventions: Supporting Collaboration Culture

Only four interventions were identified in the 15 papers. Daneshy and Bahorich (2005) highlighted that greater collaboration between operating and service companies would foster a greater understanding of each other's respective needs. This would support a more rapid use and acceptance of technology compared to an adversarial culture. Within the studies

scrutinized, several approaches to supporting collaboration in the O&G sector were identified: These included:

- **Open innovation** (OI) offers an alternative to the high research and development costs, long development cycles, resistance to change, high uncertainty and high technical risk associated with innovation by providing a structure for inter-firm alliances. Radnejad, and Vredenburg (2015, 2017) have applied OI within the upstream Canadian petroleum and petrochemical sector as a means of supporting the collaborative culture of both organisations and of the broader sector. It was found that collaboration worked successfully at the pre-competitive stage of innovation but that there were several barriers that limited the success (, e.g. leadership, corporate culture and available time).

- **Strategic dalliances** are non-committal relationships that support radical innovation in slow clock speed industries. These were employed as a method for fostering collaboration among a small service company *Twister BV* (approx. 20 employees) and *Royal Dutch Shell*, two universities in the UK and Netherlands, and an engineering firm *Noordwijk Technologies* (Noke, Perrons & Hughes, 2008). Whilst not all the relationships between the original partners remained intact, it was thought to be unlikely that the companies would have collaborated and expanded their businesses into new market segments, or that innovation would have been developed, without this approach.

- **Technology innovation systems** (TIS) are actors, networks and institutions that support the development, diffusion and utilization of new, radical technologies. They were used to support collaboration and learning between the established Norwegian O&G sector and emerging wind power sector (Makitie et al., 2018). There were mixed results with a positive impact on both the development of the wind power sector but also the diversification of O&G company strategies, but these were limited by intermittent commitment by firms to take part in the TIS.

- "**Partnering"** methods that support collaborations between the stakeholders (e.g. major clients, contractors, and operators) were successfully used as part of integrated operations by Norwegian drilling contractor (Eike, 2012) and as part of a North Sea oil field construction project called the *British Petroleum (BP)* Andrew Alliance (Barlow, 2000).

7. Discussion

Our literature review aimed to identify what, if any, research had been conducted in relation to the psychological barriers to technology adoption in O&G. While an extensive range of psychological factors have been examined relating to consumer behaviour and product usage more generally, very few research studies specifically relating to O&G were found. A common message within the 17 reviewed O&G studies was that there is a continuing need for the O&G industry to harness the potential of technology innovation and support adoption. Yet compared to other industries, a limited number of psychological factors were identified: personality (risk

aversion, exploration traits), attitudes (trust and not invented here syndrome), social (social norms), cognitive (risk perception), and organisational issues (leadership and organizational culture). Our review also aimed to identify what interventions had been developed and deployed to support technology adoption in O&G. Several methods were evident including OI, strategic dalliance and "partnering" methods to foster innovation and collaboration. However, these were typically focused towards innovation and collaboration, rather than specifically adoption. Furthermore, they did not address the underlying psychological factors, such as attitudes, motivations or leadership, which will likely influence subsequent innovation and collaboration.

The review showed that a few psychological factors that impact on technology adoption in O&G had been studied, however several significant gaps remain. What other psychological factors influence technology adoption? For example, what are the attitudes, beliefs and motivations (e.g. fear of failure, concerns over job security, passive resistance to change) that drive technology adoption behaviours. What are the social factors that act as facilitators and barriers to technology adoption (e.g. role models and social norms)? What are the decision processes and are they influenced by bias? How do social norms influence adoption behaviours? What role do on-site leaders play in persuading the workforce to accept new ways of working? It may also be valuable to differentiate the psychological factors that impact on manger's deployment decisions and end-user's adoption behaviours. Two other questions remain unanswered.

1. How do the unique characteristics of the O&G industry, such as the problem of free ridership and risk aversion, influence these psychological factors?
2. Are there empirically based interventions that can navigate the psychological and organisational barriers to technology adoption in O&G (e.g. measurement and training tools).

Much can be learned by looking at the Health and Safety journey in the O&G industry over the past forty years, particularly regarding the recognition of and improvements in human factors. For example, learning from how safety culture was introduced and developed within the O&G industry, particularly in reference to supporting safety leadership (National Academy of Sciences, 2016). Safety culture has now become mainstream through the introduction of measurement methods, diffusion of the concept and its utility for safety and performance, as well as training methods on how to support safety within the workplace (see HSE, 2000). It is possible that some of these methods may be adapted to the new challenge of technology adoption (e.g. technology adoption culture). Fostering psychological safety – the perception of the consequences of interpersonal risk taking in the workplace - would likely be valuable for supporting technology adoption through creative problem solving, collaboration and organizational learning (Edmondson, 2003).

Keeping in mind that competitive advantage comes from a combination of tangible assets, capabilities and intangible asset (e.g. reputation and Intellectual Property), innovation, technological progress, and collaboration are a strategic priority not only to maintain current competitive advantage but as tools to address unknown future challenges (Garcia, Lessard & Singh, 2014).

8. Conclusion

Whilst there are significant efforts to support and improve adoption of technology innovation in the O&G sector, there is still a need to understand the underlying psychological factors that influence technology adoption. Evidence from O&G industry bodies indicate that these psychological factors are hindering technology adoption and growth of the industry. The literature review identified that very limited relevant research specifically relating to this area has been conducted, although these factors have been extensively studied elsewhere. From the few O&G studies available, five themes relating to the psychological factors that influence technology adoption in O&G were identified, which were personality, attitudes, social, cognition, and organisational level factors. Clearly further empirical evidence is required to discover which psychological variables are influencing adoption and deployment processes for the UKCS energy industry. Several technology innovation and adoption interventions were identified but these were typically limited to innovation practices rather than adoption. The subsequent work packages of this research project will address the knowledge gaps identified through interviews (work package 2) and case studies (work package 3). Based on the findings, the final work package will involve the development and evaluation of a psychological tool set to support technology adoption in the upstream O&G industry on the UKCS.

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Appendix A

Table 1. Key models of technology innovation adoption, including key points.

Model	Key Features
Rogers (1983). Diffusion of innovations. The Free Press.	• Well applied model with a solid theoretical foundation and empirical support • Method of understanding how communication drives innovation adoption through channels in a social system. • Five attributes that are necessary for innovation adoption: relative advantage, compatibility, complexity, trialability, and observability. • Process of adoption: knowledge, persuasion, decision, implementation and confirmation.
Theory of Reasoned Action (Fishbein & Ajzen,1975). Belief, attitude, intention and behavior: An introduction to theory and research.	• Behaviour is driven by intention to perform which is driven by attitudes and subjective norms. • Attitudes are formed from salient beliefs and evaluations from prior experiences. • The Theory of Planned Behavioural (TPB; Ajzen, 1991) was also added to TRA model to include an additional component of perceived behavioural control. It was found to be a significant factor in prediction of behavioural intention and actual behaviour (Armitage & Conner, 2001).
Davis et al (1989). User acceptance of computer technology: a comparison of two theoretical models. Management science, 35(8), 982-1003.	• Key model that is based on TRA model to predict user acceptance of IT systems • Perceived usefulness and perceived ease of use are key predictors of intention to use (Davis et al., 1989) • These determinants serve as basis for attitudes, and intention to use innovation. • The model was updated to form the TAM2 which includes additional components that influence behavioural intention to use. This includes: addition of subjective norms, image and reference groups, voluntariness, experience effects and social influence (Venkatesh & Davis, 2000) • Trust and risk were also identified as part of the TAM in which attitudes, trust and perceptions of risk are interlinked (Pavlou, 2003).
Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model:	• The model was developed from the comparison of 8 key models from literature to create a unified view of the technology acceptance process.

Four longitudinal field studies. Management science, 46(2), 186-204.	• Four components that predict intention to use were identified: Performance expectancy, effort expectancy, social influence and facilitating conditions.
Hameed, M. A., Counsell, S., & Swift, S. (2012). A conceptual model for the process of IT innovation adoption in organizations. Journal of Engineering and Technology Management, 29(3), 358-390.-	• Outlines a model of innovation adoption in IT that combines all key models into one overarching model and identifies the characteristics that that impact each stage of adoption. • Initiation stage: Innovation and organisational characteristics that impact on awareness of adoption, attitude formation and proposal for deployment(adoption) • Adoption decision stage: environmental & CEO characteristics (adoption and deployment) • Implementation: end user acceptance characteristics (deployment)
Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption: A multi-level framework of determinants and opportunities for future research. Journal of business research, 55(2), 163-176.	• Propose a two-level model of innovation adoption at both the individual and organisational level • Organisational level adoption determinants: Perceived innovation characteristics (relative risks and benefits of product), adopter characteristics (size of sector and organisation, organisational structure, procedures, processes, culture and predisposition to innovate), supplier marketing efforts (targeting, communication and risk reduction), social network and environmental influences (network externalities and competitive pressures) • Individual innovation characteristics within organisations: Attitudes towards innovation, personal innovativeness (PI); social influences, and social norms. • Organisational adoption facilitators: management strategies, policies, training and education, technical support, incentives and technical structures (i.e. culture).
Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Technology, Organisation and Environment (TOE) context model Lexington, MA: Lexington Books.)	• Three aspects of an organisation's context will influence the adoption and implementation process. • Technological context: internal and external technologies that are available/relevant to the firm • Organisational context: characteristics such as size, slack, communication processes and formal and informal linking structures • Environmental context: the area in which the organisation/firm operates its business including industry characteristics and market structure, technology support infrastructure and government regulation.

Appendix B

Given the limited research anticipated, minimum selection criteria were applied as based upon Cochrane quality control (Higgins & Green, 2011): the publication was - an academic and peer reviewed study; on innovation adoption; discussed the psychological factors that influence technology adoption and innovation; was conducted within the oil and gas or petrochemical and petroleum industries. It had to be published in English. Not date restrictions were applied. Any ambiguities regarding the application of the selection criteria were resolved through discussions between the researchers involved.

A range of sources were consulted, including technology adoption and O&G technical journals, citation data bases (e.g. Science Direct OnePetro and Google Scholar), the university library catalogue and online resources (e.g. Journal of Petroleum Technology), as well as contacting academic psychology contacts in several countries to identify additional research papers.

Key words were: psychological, barriers, technology innovation, adoption, human factors, oil and gas industry, petrochemical and petroleum (P&P), exploration and production (E&P), upstream oil and gas sector, UKCS, North Sea, technology adoption, technology acceptance, deployment, organisational innovation, open innovation, change management, innovation change, and technological change management.

Appendix C

Table 2. Key O & G literature reviewed including article summary points.

Article	Sector	Country	Method	Summary Points
Bargach, S., & Hirsch, M. J. (2005, January). Role of Incentives and compensation models and Culture of Oil and Gas Industry in Technology Acceptance. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers.	Oil and Gas	International	Workshop roundtable	• Identified culture, risk, business strategy and how to reward innovation as barriers to technology acceptance.
Barlow, J. (2000). Innovation and learning in complex offshore construction projects. *Research policy*, *29*(7-8), 973-989.	Oil and Gas (Construction)	North Sea (UKCS)	Case study of an intervention: "partnering" tool to support collaboration	• Found considerable benefits during BP Andrew Alliance project construction project
Daneshy, A. A., & Bahorich, M. S. (2005, January). Accelerating Technology Acceptance: Overview. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers.	Oil and Gas	International	Workshop roundtable	• Identified key barriers to technology acceleration

Eike, M. (2012, January). Building Capacity for Innovation-A Drilling Contractors Approach to Continuous Change Management. In *SPE Intelligent Energy International*. Society of Petroleum Engineers.	Oil and Gas (Drilling)	Norway	Case study of an intervention: continuous change management for innovation	• Supporting collaboration in integrated operations using capacity for innovation framework
Hassani, H., Silva, E. S., & Al Kaabi, A. M. (2017). The role of innovation and technology in sustaining the petroleum and petrochemical industry. *Technological Forecasting and Social Change*, *119*, 1-17.	Petrochemical and Petroleum	International	Review paper	• Discusses the utility of innovation with discussion of examples of where it has been beneficial
Hirsch, J. M., Luppens, J., C., & Shook, M. T. (2005). The role of culture of the oil and gas industry in technology acceptance. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers.	Oil and Gas	International	Workshop/roundtable	• Identified industry culture and organisational culture as barrier to technology acceptance.
Mäkitie, T., Andersen, A. D., Hanson, J., Normann, H. E., & Thune, T. M. (2018). Established sectors expediting clean technology industries? The Norwegian oil and gas sector's influence on offshore wind power. *Journal of Cleaner Production*, *177*, 813-823.	Oil and Gas and wind power	Norway	Case study of collaboration intervention: Technology innovation systems	• Method for supporting collaboration between related industries (O&G and wind power)

Noke, H., Perrons, R. K., & Hughes, M. (2008). Strategic dalliances as an enabler for discontinuous innovation in slow clockspeed industries: evidence from the oil and gas industry. *R&d Management*, *38*(2), 129-139.	Oil and Gas	International	Case Study of an intervention: strategic dalliances	• Strategic dalliances are non-committal relationships that support radical innovation in slow clock speed industries
Oyovwevto, J. S. (2014). The social construction of technological innovation in the oil and gas industry. DBA Thesis.	Oil and Gas	UK	Interviews	• Technology innovation in O&G from entrepreneurship perspective
Perrons, R. K. (2014). How innovation and R&D happen in the upstream oil & gas industry: Insights from a global survey. *Journal of Petroleum Science and Engineering*, *124*, 301-312.	Upstream Oil and Gas	International	Survey (SPE membership)	• Examination of innovation in O&G using SPE members and number of patents filed as proxy for innovation
Perrons, R. K., & Donnelly, J. (2012). Who drives E&P innovation?. *Journal of Petroleum Technology*, *64*(12), 62-72.	Oil and Gas exploration and production (E&P)	International	Survey	• Focused on types of organisation were innovating
Perrons, R. K., Burgers, H., & Newton, C. (2018, September). Who Are the Innovators in the Upstream Oil & Gas Industry? Insights From the 2017 SPE Global Innovation Survey. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers.	Upstream Oil and Gas	International	Survey	• Focused on the characteristics of who were most likely to be innovators (e.g. educational background, country or origin, country currently working in).

Radnejad, A. B., & Vredenburg, H. (2015). Collaborative competitors in a fast–changing technology environment: open innovation in environmental technology development in the oil and gas industry. *International Journal of Entrepreneurship and Innovation Management*, *19*(1-2), 77-98.	Petrochemical and Petroleum	Canada	Case study of open innovation (interviews and document analysis)	• Applies open innovation as an intervention strategy to support technology collaboration
Radnejad, A. B., & Vredenburg, H. Meta-organizing for open innovation under environmental and social pressures in the oil industry. Technovation, August 2017.	Petrochemical and Petroleum	Canada	Case study of open innovation (interviews and document analysis)	• Applies open innovation as an intervention strategy to support technology collaboration with guidance on where and how to best direct support
Ramírez, R., Roodhart, L., & Manders, W. (2011). How Shell's domains link innovation and strategy. *Long Range Planning*, *44*(4), 250-270.	Oil and Gas	International	Development of intervention: innovation management system Game Changer	• Use actor network theory to explain success of GameChanger.
Rao, V., & Rodriguez, R. (2005, January). Risk/Reward Concepts in Technology Adoption in the Oil and Gas Industry. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers.	Oil and Gas	International	Workshop/ roundtable	• Identified risk aversion and uncertainty in technology innovation as barrier to technology acceptance.

Saetren, G., & Laumann, K. (2015). Effects of trust in high-risk organisations during technological changes. Cognition, Technology & work, 17, 131-144.	Oil and Gas	Norway	Interviews and observations	• Exploring the effect of trust on drilling crew's acceptance of new automated drilling technology.