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FBK-IRVAPP Working Paper Series

Working Paper No. 2024-01

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January 2024

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Abstract

Innovating product design is crucial for firms operating in the digital sector as it is closely linked with innovation capability and, therefore, with firm performance and productivity. In this paper, we run a randomized controlled trial to assess if participating in an open innovation initiative increases SMEs' capability to design more competitive digital products. More specifically, the intervention aimed at increasing firms' knowledge of the Design Sprint and their readiness to implement user-centered design techniques. 190 SMEs based in 7 different European countries took part in the field trial in spring 2021. We find that the intervention increased participants' knowledge about user-centered design methods, although no statistically significant effects are found on participants' intention to adopt that in their firms. This may be traced back to organizational and financial constraints typically related to the small-sized firms involved.

JEL Classification: D22, M31, O31, O36

Keywords: Open Innovation, SMEs, Randomized Controlled Trial, User Experience Design, Design Sprint

Acknowledgements

This paper builds on the results of the 200SMEchallenge randomized controlled trial, a design-driven project from H2020-INNOSUP-2018-2020 programme, aiming to support open innovation in SMEs (Small and Medium Sized Enterprises). The project allowed seven partnering innovation agencies to set up and deliver an open innovation contest supporting the adoption of user-centered product design in SME. More information about the project can be found at https://www.200smechallenge.eu/. This article provides the complete set of results and robustness tests as well as a more thorough discussion for an academic audience.

We would like to thank all partners involved in the 200SMEchallenge project for allowing the experiment to take place. Without their work and the work of the people involved in the 200SMEchallenge project, this paper could not have been written. All remaining errors are ours.

We also thank the European Commission for funding the 200SMEchallenge project (https://cordis.europa.eu/project/id/824212), the European Innovation Council, and the SMEs Executive Agency (EISMEA) for the support provided to us during its implementation.

An ethics approval was not necessary for the study according to European Union and EU national laws in force at the time when the research was conducted. Personal data from individuals participating in the project were collected and treated according to General Data Protection Regulation (GDPR) compliant data treatment policies.

The authors have no relevant financial or non-financial competing interests to report.

1 Introduction

The success or failure of a business often hinges on the user experience (UX) of its products and services. Notable cases, such as the 2012 Apple Maps release (Gassée, 2012), the 2014 Marks & Spencer website relaunch (McDonnell, 2014), and the 2017 Snapchat redesign (Hern, 2018), serve as reminders of the millions of dollars lost in market value due to poor UX. Conversely, minor changes, like adjusting a single button on an ecommerce website, can generate substantial revenues (Spool, 2008). In today's fast-paced environment, where user demands constantly evolve and product life cycles shorten, continuous improvement and adaptation of UX are crucial for firms offering digital products and services.

UX can be defined as the complex of perceptions, thoughts, emotions, behaviors emerging before, during and after a person's interaction with a product, service or system (ISO 9241-210:2019[1]). Although the salience of UX does not only concern large firms, small and medium-sized enterprises (SMEs) are often less aware of it and generally lack the needed innovation capability i.e. the ability to improve their products and services. In general, for the latter, investing in innovation (capability) is often less feasible than for larger firms due to their limited size and resources. Consequently, it is plausible to think that they tend to prioritize short-term, results-driven investments in innovation.

UX design can enhance an organization's innovation capability by fostering a deeper understanding of user needs, promoting iterative design processes, identifying new opportunities, creating a competitive advantage, enabling adaptability, and cultivating a culture of innovation. Since innovation capability is inherently linked with firm competitiveness and productivity, firms with a higher innovation capability are often more adaptable and responsive to market changes (Ahn et al., 2016; Börjesson & Löfsten, 2012; Terziovski & Samson, 2007).

The present study seeks to evaluate whether engaging in a brief open innovation contest focused on UX design can impact SMEs' capability to design better digital products and services, ultimately bolstering their innovation capability. In this vein, open innovation

[1] ISO 9241-210:2019 document contains requirements and recommendations for human-centered design of interactive systems defined by the International Organization for Standardization (ISO).

represents "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology" (Chesbrough et al., 2006).

The initiative under study, called UX Challenge, aims to foster a deeper understanding among firms about the advantages of user-centered design.[2] It consists of a special kind of Design Sprint (Banfield et al., 2015; Knapp et al., 2016), where SMEs can submit product development or innovation challenges about their digital products and services to teams of university students led by experts in order to find new solutions and improvement opportunities. The Design Sprint is a rapid design method particularly suited for digital contexts; it fits into the greater Design Thinking paradigm while also applying agile development principles. Its structured yet nimble process helps organizations to address a wide range of digital challenges, making it a valuable asset in the digital economy's search for innovation and user-centered solutions.

This article draws on a randomized controlled trial (200SMEchallenge) carried out in seven European countries (Italy, Germany, Finland, Lithuania, Spain, Estonia, Denmark), to evaluate the effectiveness of the UX Challenge on SMEs' "Digital Design Readiness and Awareness" (DDRA).[3] We introduced DDRA as a proxy for innovation capability and consists of a mix of knowledge, attitudes and behaviors linked to SMEs' take-up of user-centered design approaches in their activity.

Our findings suggest that the UX Challenge is an effective approach to improve participants' knowledge about Design Sprint and user-centered design. This is crucial if we consider that SMEs are particularly unaware of the importance of design for improving their (cap)ability to optimize digital products and services. While the project successfully met its purposes, this study also reveals that the intervention failed to improve any positive shifts

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[2] User-centered design is a design philosophy that can be adopted to perform UX design. It puts the user as the central focus throughout the development process, prioritizing their needs, behaviors and feedback to deliver the most usable and valuable experiences.

[3] The trial was pre-registered in the AEA-RCT registry on Oct, 8 2020 (AEARCTR-0006246).

in attitudes towards user-centered design methods, nor did it foster a stronger propensity or desire to implement them within the treated firms compared to the control group. This may likely be attributed to organizational and financial constraints, especially for firms with fewer than six employees and a median turnover of 150,000 euros. Nevertheless, these findings offer insights into intervention effectiveness, considering short or long-term outcomes, intervention structure, and target firms.

This paper contributes to the literature on open and digital innovation for SMEs, with particular reference to contest-based initiatives focused on UX design, by providing preliminary experimental evidence on the effects of a UX Challenge on SMEs' capability to better design digital products and services.

2 Theoretical Framework

2.1 The Role of Design in Driving Firms' Innovation

In the fields of management and entrepreneurship, a significant boost to the interest in design methods came mainly from extra-academic channels aimed at a business audience, such as design firms and practitioners, advocating the value of design principles, approaches, and techniques—encapsulated in the concept of Design Thinking—to general problem solving inside firms (Johansson-Sköldberg et al., 2013). Since the concept of Design Thinking emerged outside the realm of scholarly literature, there is still ongoing debate about how to definitively define it (Liedtka, 2015). While Brown (2009) popularized the concept as a ”discipline” that uses designer working methods to address human needs ensuring both technical feasibility and business viability, it may be more accurate to characterize Design Thinking as a paradigm (Verganti et al., 2021). Design Thinking represents an overarching mindset and approach to innovation and transformation that is distinguished from the practice of design itself. As a paradigm, Design Thinking principles and tools can potentially be applied not only within the domain of design, but more broadly to an array of challenges across multiple fields and industries. Design Thinking integrates intuitive and analytical thinking to address complex, ill-defined[4] challenges that conventional linear, logical and analytical business tools fail to address (Hobday et al., 2012). Its creative and holistic nature fosters the reframing of problems and the adoption of new outside-the-box perspectives to seize less obvious opportunities and generate innovative solutions (Dell'Era et al., 2020).

Since neoclassical and evolutionary views of innovation such as Schumpeter's (1934/ 1983) regards it fundamentally as a creative process led by visionary individuals relying on their imagination and intuition, rather than something systematically pursued through rational decision-making (Hospers, 2005), the Design Thinking paradigm with its emphasis on creativity and experimentation can be considered an appropriate approach for firms' innovation (Schweitzer et al., 2023; Tselepis & Lavelle, 2020; Ward et al., 2009). Several scholars have indeed suggested that Design Thinking is a dynamic capability for innovation (Carlgren et al., 2014; Magistretti et al., 2021; Sahakian & Ben Mahmoud-Jouini, 2023), as it improves a firm's overall innovation capability i.e. its "muscles for innovation" (Börjesson & Elmquist, 2011). Within the resource-based view of firms, capabilities are "embedded non-transferable firm-specific resources" that enable the implementation and exploitation of other resources (Barney & Clark, 2007). Dynamic capabilities are specific type of capabilities used to create, extend, upgrade and protect the firm's resources to adapt to a changing business environment (Teece, 2007; Teece et al., 1997); they are thus considered a source of competitive advantage as they allow firms to sense and seize opportunities and accordingly reconfigure their resource-base. As a dynamic capability, Design Thinking improves firms' preparedness and capability for innovation, enabling them to: sense new opportunities based on their understanding of user needs; seize opportunities by prototyping, developing and testing solutions; reconfigure the problem by adopting

[4] The scholarly interest in design emerged in the 1960s, as researchers sought to understand the cognitive processes, working methods, and problem-solving abilities of designers (Johansson-Sköldberg et al., 2013). Design established itself as a discipline in its own right, characterized by its distinct "way of thinking and communicating" (Archer, 1979), therefore different from both science and humanities but equally valuable, and capable of solving particular categories of problems defined as ill-defined and wicked (Buchanan, 1992). Ill-defined wicked problems refer to complex issues that lack clear formulations and involve many interconnected elements that make them seem impossible to fully solve; these problems do not have well-specified objectives, solution paths, or expected outcomes, and their requirements are vague or incomplete (Rittel & Webber, 1973).

different approaches and perspectives (Magistretti et al., 2021).

Within the Design Thinking paradigm, user-centeredness constitutes one of the most important traits (Carlgren et al., 2016), giving name to a specific approach called user-centered design (Norman, 1990; Norman & Draper, 1986). Emerged in the early nineties, this approach places a strong emphasis on the active and ongoing involvement of end users throughout the design and development stages. It involves understanding user behaviors, motivations, and challenges through methods such as interviews, focus groups, workshops, etc. By actively engaging with users, designers can gather valuable insights, refine prototypes, and make informed decisions that prioritize user needs. This continuous interaction ensures that the final product is not only functional but also aligns closely with user expectations, resulting in improved usability and overall user satisfaction.

Especially but not exclusively in the context of digital products and services, Design Thinking and user-centered design find application in the Design Sprint, a collaborative and time-constrained process developed by Google Ventures, aimed to quickly develop and validate ideas with real users' input (Banfield et al., 2015; Knapp et al., 2016). The process typically lasts five days, although it can be shortened, extended, or repeated according to specific needs, and consists of five discrete phases: understanding, diverging, converging, prototyping, and testing. Its advantages lie in its speed, cost effectiveness and results-oriented approach, that let organizations of any scale to prevent failures and speed up the prototyping and validation of ideas.

In the current paper, we use the comprehensive term "digital design" as an encompassing construct that incorporates the three pivotal concepts of Design Thinking, user-centered design and Design Sprint, as they all support the innovation and development of digital products and services.

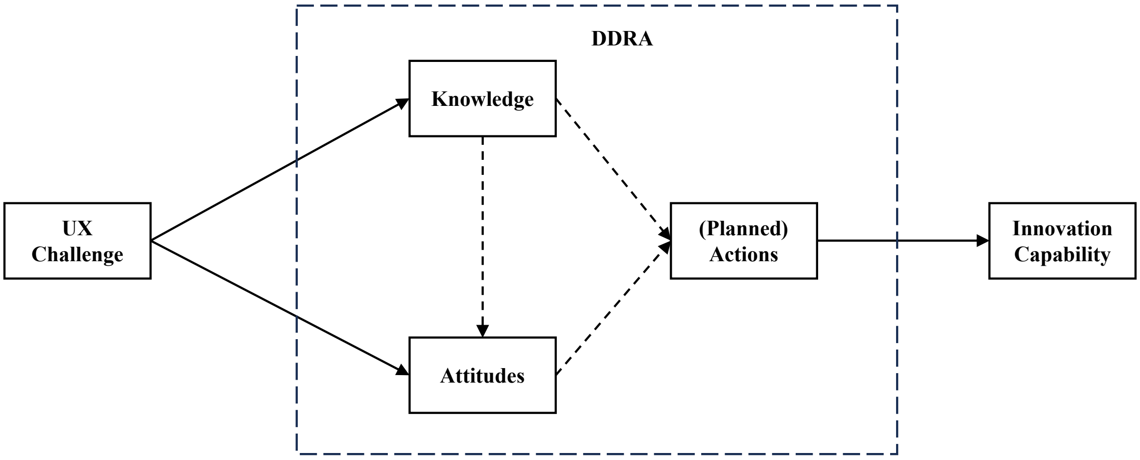
2.2 The UX Challenge's Theory of Change

Many initiatives have been conducted to increase the innovation capability of SMEs through design and, specifically, Design Thinking (e.g. Cawood (1997), Landoni et al. (2016), Lawlor et al. (2015), Lockwood et al. (2012), Mortati and Villari (2016), and

Ward et al. (2009)). This paper focuses on a specific initiative named UX Challenge. The UX Challenge is a shorter two-day version of a Design Sprint, where university design students and young professionals organize in teams—with the help of expert professionals or researchers—improve the user experience of digital products and services submitted by SMEs, involving real end users as testers. At the end of the challenge, a jury awards the winning team(s). This initiative is heavily inspired by hackathons, and could even be considered one. Born as time-bounded problem-focused computer programming events, hackathons may now be more generally regarded as fast-paced contests in which people work in teams over a short period of time to address complex problems or foster digital innovations (Briscoe & Mulligan, 2014; Heller et al., 2023). Hackathons have been used as a sourcing method for firms to perform inbound open innovation (Granados & Pareja-Eastaway, 2019; Uffreduzzi, 2017), which means seeking new knowledge from external sources to improve and accelerate internal innovation processes (Chesbrough et al., 2006). Thanks to their organizational features such as flexibility and adaptability to change, SMEs can exploit open innovation to overcome several challenges: lack of resources, skill gaps, increasing competition, commoditization pressure (Frattini et al., 2018). Several studies find that open innovation has a positive, although limited, effect on SMEs' innovation performance (Chen et al., 2011; Dufour & Son, 2015; Laursen & Salter, 2006; Parida et al., 2012), suggesting that they can benefit from open innovation even more than larger firms (Rippa et al., 2016; Spithoven et al., 2013). However, to optimally do so they require some capabilities such as absorptive capacity, networking skills, and orchestration capabilities (Usman et al., 2018).

Many different conceptualizations have been proposed to measure innovation capability (Mendoza-Silva, 2021; Saunila, 2020). In order to frame and adapt this concept to our purpose, we propose to gauge short-term innovation capability as an outcome of the UX Challenge on SMEs through "Digital Design Readiness and Awareness" (DDRA), assuming a positive link between the two. DDRA is meant to capture three specific intra-organizational determinants of innovation capability: knowledge, attitudes, and planned actions (see Figure 1). Here, we explain in which way these three aspects are intertwined.

Figure 1: The UX Challenge's Theory of Change



First, increased knowledge about digital design comes from inbound knowledge flows. While interacting with students, researchers, and professionals, SME representatives can not only find innovative solutions to their current UX-related problems, but also learn digital design methods and principles that may later guide their future innovation processes; at the same time, interacting with real end-users SMEs can acquire knowledge about their needs, contexts, experiences, and preferences (Bigliardi & Galati, 2018). The new acquired knowledge can basically act as a spark for creativity and innovation, as its combination with prior existing knowledge permits new associations and linkages that could potentially be unprecedented (Cohen & Levinthal, 1990). A great deal of literature confirms indeed the link between external knowledge search and recombination and the generation of high valuable innovations inside firms (Savino et al., 2017).

Second, alongside the change in knowledge, a change in attitudes is also expected, as the UX Challenge allows SME representatives to experience user-centered design techniques in action and accordingly form beliefs about them. Beliefs constitute the cognitive component of attitudes, which in turn may be responsible for the actions taken. Attitudes are in fact considered crucial in the process of innovations adoption, as they can be precursor of or barriers to behavior (Burcharth et al., 2014).

Finally, the DDRA model entails planned actions as the result of knowledge and attitudes regarding digital design. This is consistent with Rogers' innovation-decision process (Rogers, 2003), which places the step of deciding to potentially implement the innovation after the steps of acquiring information about the nature and functioning of the innovation and forming an attitude toward it. The complete conceptual framework is reported in Figure 1.

3 Experimental Design and Methodology

3.1 Sample Selection and Descriptives

European innovation agencies taking part in the 200SMEchallenge project recruited 208 SMEs across seven EU regions through an open recruitment campaign, which took place between October 2020 and February 2021. Firms Applied with a product/service and a related design problem (challenge) that was evaluated in terms of suitability.[5] To be eligible a firm had to be an SME (to employ less than 250 employees and with a 2019 turnover below 50 million or a balance sheet total lower than 43 million)[6]. In addition, to be selected for the intervention, firms had to provide information on the product/challenge they wanted to include in the challenge and some information about the reference person within the firm. After this process, 190 firms were included in the study, which involved the administration of a baseline survey (BS), the provision of the UX Challenge to a randomized treatment group of SMEs, and a follow up survey (FUS).

Table 1 shows the descriptive statistics for the sample responding to the baseline questionnaire. Eight firms out of ten have at least one designer among their employees, and on a scale of 0-7, they show an average expertise in digital design of 4.6 (dd_exp). The suitability score of the products and challenges submitted to the UX Challenge, which ranges from 5 to 25, was high among selected firms, with an average level of about 20 points.

The information and communication technology (ICT) sector constitutes the largest

[5] Applications were rated by each national partner on a score from 5 to 25, resulting from the following five indicators: ease of use; possibility to involve generic users; interactivity; innovative features; motivation and expectations.

[6] All monetary amounts are expressed in euros.

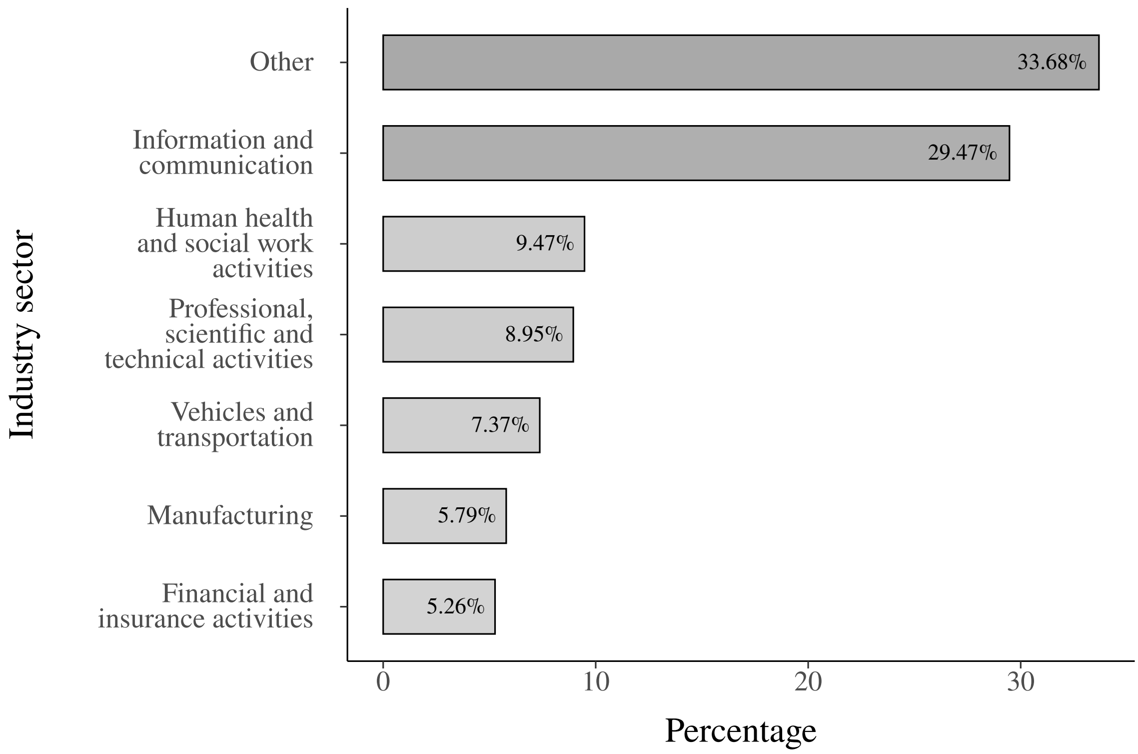
Table 1: Firms and respondents characteristics

	Mean	Median	SD	N
		Firm Characteristics		
Employees	19.54	6.00	34.45	190
Employing a designer	0.82	1.00	0.38	190
Digital Design Experience	4.55	5.00	1.61	190
Suitability Score	19.52	20.00	3.12	190
		Individual Characteristics		
Male	0.73	1.00	0.44	190
Experience	15.81	15.00	8.77	165
Master's Degree	0.59	1.00	0.49	190

Note: the number of respondents may be less than 190 if there are no answers to specific items

segment, encompassing 29% of all firms in the sample, followed by human health and social work, professional and scientific activities and the manufacturing sector (Figure 2). In general, more than half of the firms operate in the service sector.[7]

Figure 2: Sectoral distribution of firms in the sample



[7] Other encompassess all the NACE 1 sectors not represented in the other categories

Concerning individual participants' statistics, we can see that 73% of them were male, with an average working experience of 16 years, and that 59% of them held a University degree.

3.2 Measures of DDRA

DDRA is formed by three main dimensions: knowledge, attitudes and planned actions. The first dimension (*1. Knowledge*) comprises three distinct indicators: *1.1 General Design Knowledge*, *1.2 Design Sprint Knowledge*, and *1.3 Knowledge to Implement Design Sprint*. The first indicator is aimed at capturing respondents' self-perceived general knowledge about i) User-Centered Design, ii) Design Thinking and iii) Design Sprint. The second indicator is aimed at measuring respondents' actual knowledge about the contents of the specific five phases of the Design Sprint. The third indicator captures respondents' self-reported ability to perform a Design Sprint and, more precisely, to implement its five phases. The first and the third indicator are measured utilizing a Likert-scale question subjected to principal component analysis, while the second indicator emerges as a result of quiz-like questions. Respondents were provided with four answer options, with varying point allocations based on the accuracy of their responses. Additionally, alternative scoring methods were employed to ensure the index's robustness.[8]

The second dimension (*2. Attitudes*) is measured with one additive index based on the responses to a set of items aimed at capturing the benefits that their firms would enjoy from each of the five phases of Design Sprint for their firm.

The third dimension (*3. Planned actions*) is measured through two indices, which capture respondents' desire and expectations about foreseen investments and adoption of user-centered design by their firm in the next 6 to 12 months. The first block of questions asks the extent to which the respondents would like their firm to undertake any of the listed actions, while the second block asks the extent to which they believe that their firm will actually undertake the same list of actions. Both questions are Likert questions and they

[8] See Appendix for more information about the single items as well as methods employed to ensure the index's robustness.

are analyzed with principal component analysis.

Table A.3 in the appendix provides a detailed description of how each outcome variable was constructed, while the wording of the questions and the items can be found in the questionnaire directly (see appendix). To improve understandability and comparability of the computed scores, all of them have been normalized, having 0 as a minimum value and 10 as a maximum value.

On a scale from 0 to 10, table 2 shows the descriptive statistics with regard to the outcome variables that constitute our indicator of Digital Design Readiness and Awareness measured in the BS. Every single measure is normalized on a 0-10 scale. Applicants show an average self-perceived general knowledge about general design of 6.3 and an average knowledge of implementing Design Sprint of 6.5. In the same way, participants show an average level of positive attitudes toward digital design of 5.5. On average, the extent to which applicants wish that their firms take action in regard to digital design is estimated at 6.6, while a lower value (5.7) is found when applicants are asked to state whether they expect that their firm will actually takes concrete action.[9]

Table 2: Baseline DDRA measures

	Mean	Median	SD	N
1.1 General Design Knowledge	6.33	6.59	2.32	190
1.3 Knowledge to implement Design Sprint	6.45	6.64	2.03	190
2.1 Attitude towards Design Sprint	5.49	5.77	2.56	190
3.1 Desire of adoption of design methods†	6.62	6.63	2.37	190
3.2 Expectation of adoption of design methods†	5.67	5.74	2.14	190

† by the Company in the next 6-12 months

The difference between the last two variables is highly statistically significant (t=6.4, p-value=.00). From an initial descriptive analysis, it can be seen that the participants, already before receiving the intervention, wished that their firms would engage more in digital design than they did.

[9] Design Sprint knowledge was not asked in the BS to avoid a learning effect.

3.3 Randomization, survey participation and attrition

After completion of the baseline survey (BS), firms were assigned to either a treatment group (N=60) or a control group (N=130) following a randomization design stratified according to the country and level of design experience of the candidates. Previous design experience was selected as a variable predicting pre-treatment outcomes. Consequently, a stratified randomization design was conducted within each country. Randomization was carried out as soon as a country officially closed its recruitment and the list of candidates was checked and established. The outcome of the randomization was then communicated to the firms.

Table 3 shows the difference between treated and control units according to observable characteristics and survey responses. All in all, the two groups' baseline characteristics are, on average, equivalent, as evident from t-tests: the test shows no statistically significant differences between the treatment and control group's values of the observed baseline characteristics of firms and individual respondents. Even if not statistically significant, some differences between the two groups are worth noting. At the firm level, control firms are more concentrated in the ICT sector (31.5% vs 25% in the treatment group). At the respondent level, control group applicants show a younger age and a higher proportion of Master-level graduates (61 vs 55%). When considering pre-treatment outcomes, the two knowledge indicators are less balanced than the others across the two groups. Overall, the observable characteristics cannot predict treatment assignment, hence the groups are confirmed equivalent based on the baseline characteristics.

Three weeks after the completion of the UX Challenge, all firms were invited to fill in a Follow Up Survey (FUS). Between April and May 2021, the FUS was collected with a response rate of 73.2%, but with large differences between the two groups: 95% of the treatment group responded in comparison to 63.1% in the control group. Even if the same protocol (timing, invitation messages and planned reminders to contact firms) was followed, the final differential attrition consists of 31.9 percentage points, with some between-country heterogeneity. In order to check if, based on the observed baseline characteristics, this differential attrition introduces bias in the comparison of the treatment and the control

Table 3: Equivalence balance test

	Controls (mean)	Treated (mean)	T-test (p-value)	Std. diff.[a]
Pre-intervention outcomes				
1.1 General Design Knowledge	6.241	6.511	0.457	.116
1.3 Knowledge to implement Design Sprint	6.372	6.605	0.464	.114
2.1 Attitudes towards Design Sprint	5.479	5.502	0.955	.001
3.1 Desire of adoption of design methods†	6.572	6.717	0.695	.061
3.2 Expectation of adoption of design methods†	5.620	5.781	0.630	.075
Company characteristics				
Company ICT sector (%)	0.315	0.250	0.361	-.142
N. of employees	19.054	20.583	0.777	.044
Company has research collaboration (%)	0.485	0.500	0.845	.030
Company has a designer (%)	0.815	0.833	0.766	.046
H.E. graduates (%)	79.426	79.875	0.920	.016
Respondent characteristics				
Design experience (0-7)	4.531	4.600	0.784	.043
Older than 40 yrs old (%)	0.369	0.483	0.138	.231
Has a master degree (%)	0.615	0.550	0.396	-.132
Suitability score (5-25)	19.469	19.633	0.737	.052
N	130	60	190	190

† by the Company in the next 6-12 months
[a] Standardized difference (standardized effect size)

groups, a number of checks have been performed in order to check if: i) the treated-control difference in attrition is determined by firms and applicants' characteristics or pre-treatment outcomes (LPM on the probability of responding to the FUS), ii) those answering the FUS are, on average, equivalent to those not answering it (t-tests on the subsample of the control group), iii) statistically significant differences exist between the treatment and control group's values (similar equivalence test as that run in table A.3, but conditioning only on FUS respondents) and iv) a joint test of significance of the equivalence test in iii). All the tests are included in the appendix and suggest that there are no firm or participant-relevant characteristics associated with the probability of answering the survey. In other words, there is no clear indication that those control group subjects refusing to take part in the follow-up survey are systematically different from those who decided to participate.

3.4 Estimation approach

The impact of the UX-Challenge is estimated on the outcome variables identified above. Technically speaking, the produced impact estimates are 'intent-to-treat' (ITT) estimates, because "assignment to the treatment" rather than "receiving of the treatment" is considered. To account for the randomization strata and address the potential bias induced by differential attrition, we estimated regression-adjusted ITT. Three main model specifications were performed: i) a linear regression model (OLS) with stratification variables, accommodating the stratification design and different allocation ratios; ii) an OLS which adds the pre-treatment measure of the outcome (where available, i.e. not for the quiz-based outcome) to improve statistical precision and adjust for possible imbalances and iii) an OLS adding the product/challenge suitability score, a dummy variable indicating whether the firm is operating in the ICT sector, as these variables, were found to be weakly unbalanced or associated with FUS non-response. In addition, this model also includes a dummy to identify if FUS respondents were the same as BS respondents (93% were the same person). Finally, due to the limited sample size and the large differential attrition, we present here the estimates of the third specification.

4 Findings

Table 4 shows the effects of participating in the UX Challenge on the three dimensions of the DDRA: knowledge, attitudes and planned actions. As the knowledge dimension is made up of three sub-dimensions, coefficients are estimated on each single sub-dimension.

Model specification (iii), i.e. the most restrictive model, was chosen as the benchmark. In this way, all estimates from the stratified randomisation, the firm and the respondents characteristics, as well as the results before receiving the treatment, are taken into account in the model. This allows us to better address the loss of observations in the control group. The table also reports the averages for the control group. Moreover, to better interpret the magnitude of the impacts, for each outcome, the standardized effect size (Std. effect size) of the third model is also computed and reported.

In general, results show that the intervention had significant effects in increasing *1. Knowledge*, specifically *1.2 Design Sprint Knowledge* and *1.3 Knowledge to Implement Digital Design*. These are large, positive and statistically significant: +1.1 points (19% increase) on the effects of the UX Challenge on *1.2 Design Sprint Knowledge* and +0.71 points (12% increase) on *1.3 Knowledge to Implement Digital Design*. The standardized effects size confirms the higher magnitude of the former on the latter. Therefore, data shows that participating in a UX Challenge increases the methodological knowledge of the Design Sprint method in SMEs by almost one fifth, and increases the self-perceived capability to actually carry it out (e.g. applying it to a real project) by 12%.

Positive but not significant impacts are reported for the self-perception about *1.1 General Design Knowledge*. This could be due to the fact that firms already operating in the digital field already have relatively high general knowledge of these methods. This is confirmed by the fact that the average level of the control group (those who did not receive the intervention) was already equal to 6.3/10. Indeed, the intervention focused on modifying more specific knowledge as *1.2 Design Sprint Knowledge* and *1.3 Knowledge to Implement Design Sprint*.

When it comes to attitudes and planned action towards the implementation of digital design methods, the UX Challenge had non-significant effects. Both the coefficients of the dimensions *2. Attitudes* and *3. Planned actions* are not significant, with the latter also very small in magnitude.

The discrepancy between the positive impacts found on attitudes towards digital design and the nil impacts found on the two indicators of planned actions may be accounted for by the respondents being aware of factual constraints for firms to invest more in digital design, which was high already before the intervention (table 2) and seems to persist after its conclusion. To test if this is the case, we check on the information collected in the FUS data. Table 5 shows the differences between the treatment and the control group with regard to all the obstacles and constraints that firms would face in undertaking digital design approaches, as reported by the participants. It represents the share of respondents who declared probable, very probable or definitively in each single item.

Table 4: Effects of the UX Challenge (OLS)

	Control mean	ITT	C.I.	Std. effect size	C.I. effects size	Controls	N
1. Knowledge							
1.1 General Design Knowledge	6.3	0.361	[-0.289,1.012]	0.170	[-0.136,0.476]	Y	139
1.2 Design Sprint Knowledge	5.9	1.096***	[0.294,1.898]	0.435***	[0.117,0.754]	Y	139
1.3 Knowledge to implement Design Sprint	5.9	0.711**	[0.026,1.397]	0.337**	[0.012,0.662]	Y	139
2. Attitudes							
2.1 Attitude towards Design Sprint	5.0	0.447	[-0.382,1.2777]	0.180	[-0.154,0.513]	Y	139
3. Planned actions							
3.1 Desired of adoption of design methods†	6.0	-0.179	[-0.964,0.605]	-0.078	[-0.417,0.262]	Y	139
3.2 Expectation of adoption of design methods†	4.9	-0.096	[-0.749,0.556]	-0.044	[-0.346,0.257]	Y	139

95% confidence intervals in brackets. * p<0.10, ** p<0.05, *** p<0.01.
† by the Company in the next 6-12 months.

It is worth noting that the intervention was effective in reducing the perception of obstacles in the process of implementing user-centered design approaches, such as the lack of qualified personnel and the lack of information on user-centered methods, which were the main objectives of the intervention. However, the discrepancy that exists between the knowledge on the one hand and the attitude and willingness to implement the acquired methods, as seen in Table 4, is reflected in several dimensions, such as risk aversion, the presence of rigidities at the corporate level, the responsiveness of customers, and the belief that these methods can lead to benefits at the corporate level.

All this may be traced back to the size of small firms (as shown in table 1): being on average small, they are more risk-averse, less favorable to product change, more dependent on the customer's structure and therefore also less convinced that the adoption of these practices can make a real contribution to their daily business. Further discussion about this is provided in the next section.

Table 5: Obstacles that firms would face in undertaking digital design approaches (% of respondents answering "probably", "very probably" or "definitely")

Variable	Treated	Control	
1. Prior investments	33.30%	34.10%	
2. Market conditions or excessive perceived economic risks	26.30%	18.30%	
3. Organizational rigidities within the enterprise	8.80%	14.60%	
4. Lack of qualified personnel capable to coordinate and drive such initiatives	**8.80%**	**23.20%**	**
5. Lack of information on how user-centered design methodologies work	**5.30%**	**18,30%**	**
6. Lack of information on market suppliers (do not know potential service providers)	**3.50%**	**11.00%**	*
7. Insufficient flexibility of regulation or standards	1.80%	6.10%	
8. Lack of customer responsiveness to new goods or services	19.30%	8.50%	
9. Lack of trustworthy evidence about the benefits of these methodologies (e.g. ROI - Return on Investment)	17.50%	14.60%	
10. Lack of awareness of benefits of these methodologies	12.30%	13.40%	
11. We fear that adopting these methodologies will disrupt our current product development practices	5.30%	11.00%	
12. We do not cover the entire manufacturing process (the interaction design is done by our suppliers or clients)	3.50%	12.20%	

Statistical significance: *p<0.10, **p<0.05, ***p<0.01

5 Discussion and conclusion

Between October 2020 and February 2021, the European Innovation Agencies participating in the 200SMEchallenge project recruited 208 SMEs in seven EU regions through an open recruitment campaign to participate in a User Experience Challenge (UX Challenge) pivoted on the Design Sprint methodology. The goal of the project was to raise awareness of the benefits of user-centered design in an open innovation setting. To assess the causal impacts of the intervention, access to the UX Challenge was strictly dependent on randomization. The evaluation of the effectiveness of the UX Challenge was conducted with respect to a proxy of innovation capability called Digital Design Readiness and Awareness (DDRA), which consists of a mix of knowledge, attitudes, and behaviors related to SMEs' adoption of user-centered design approaches in their business.

The results suggest that the UX Challenge is a promising way to improve participants' knowledge about Design Sprint and digital design, and their confidence in adopting such methods. The intervention had significant effects in increasing their knowledge of digital design, particularly the methodological and practical knowledge of the Design Sprint, increasing their level by 19 per cent and 12 per cent, respectively, compared to the control group. Additionally, the intervention significantly decreased participants' perception of barriers to adoption due to lack of knowledge and skills. Positive but not significant impacts are reported for the self-perception of general design knowledge. This could be due to the fact that firms operating in the digital field already have a relatively high general comprehension of digital design (6.3 on a 0-10 scale is the average level of the control group) and that the intervention went to modify more specific knowledge, namely Design Sprint Knowledge and Knowledge to Implement Digital Design, rather than the general one. In fact, it is plausible to think that firms that employ a designer (82% - see table 1) or that operate in the ICT sector (29%) have, at least, a basic knowledge of digital design, as shown in the pre-treatment descriptive statistics (table 2).

Participants show non-significant improvements in attitudes towards digital design. A possible explanation for the insignificant effect may relate to the intensity of the intervention: the UX Challenge is a condensed version of the Design Sprint offered "as-a-service" by teams of university students supported by experts, in only two days. It may be that this setup is not sufficient to change attitudes permanently. In the same vein, participants did not show any higher intention or wish to implement user-centered design methods in their firms (planned actions) as compared to the control group, highlighting the ineffectiveness of the intervention to change this dimension.

In general, data suggests that organizational and financial constraints may be the reason behind this discrepancy between the largely positive impacts on knowledge and the zero impacts on intention to adopt Design Sprint. Additional analysis on obstacles that firms would face in undertaking digital design approaches suggests that they tend to be particularly risk-averse, characterized by internal rigidities and with a market that is relatively unresponsive to this type of innovation, such as a very localized market typical of many small firms. In this sense, a two-day intervention may not be enough to change their mind and plans. Furthermore, these dynamics can be traced back to the average small size of the involved firms: more than half of them have less than six employees, with a median turnover lower than 150.000 euros. This helps to understand why, regardless of the treatment, the firms involved do not see sufficient benefits in investing in this type of benefit.

We demonstrated that the UX Challenge format manages to enhance firms' methodological and practical knowledge about the Design Sprint, a state-of-the-art reference method for implementing user-centered design in digital product development. Several implications arise for practitioners (innovation managers, open innovation managers, product managers, HR managers, and, more in general, entrepreneurs). The UX Challenge may be utilized for professional training purposes as a viable action to impact personnel skills about design methods, especially in those firms where cultural or organizational barriers in the adoption of these methods may exist. In addition, the UX Challenge may be utilized by policy makers as well as innovation intermediaries (innovation agencies, public development authorities, science parks, incubators and accelerators, industry associations) to foster user-centered innovation at an ecosystem level thanks to its open innovation setting that allows to engage together key players in the digital innovation supply chain (product development companies, service providers, university students, researchers, intermediaries). Finally, we could assume that similar open innovation Challenges could be devised and activated around state-of-the-art product innovation methodologies other than user-centered design, to the extent of improving SMEs readiness of adoption of other innovation methods or key enabling technologies (e.g. artificial intelligence, additive manufacturing, blockchain, etc.), opening avenues for considering innovation Challenges as fully fledged innovation support policy tools for SMEs across technological domains and industries (Franzò et al., 2023).

To the best of our knowledge, this is the first and only experimental study on the impact of an innovation contest on user-centered design offered as-a-service to digital firms with the aim of increasing the readiness of adoption of user-centered design methods. Future studies are needed to consolidate these findings. On the methodological side, this study suffered from small sample size that limits the statistical power of the experiment, and from a very high differential attrition, due to the much lower response rate in the follow up survey obtained in the control group. A number of statistical checks and a range of different impact estimation approaches have been performed, and these are to some extent reassuring that attrition was not systematically linked to some relevant firm or participant characteristic. However, future studies in this field should assign highest priority to experiment designs or incentives mechanisms aimed at reducing attrition.

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A Appendix

A.1 Additional Checks

A.1.1 Assignment to treatment weights

To check if the different treatment allocation ratios across blocks bias the results, the main impact models are re-estimated, including inverse probability weights. These weights are defined as 1/p for treated units and 1/(1-p) for control units, where p refers to the probability of assignment to treatment[10]. Results are available upon request.

A.1.2 Multiple outcomes

Considered that the effects are estimated on six different outcomes, there's a chance that the two statistically significant results are purely to chance. In other words, the risk of incorrectly rejecting a null hypothesis (i.e., making a Type I error) increases. To check this, the so called 'Bonferroni correction' is performed. The Bonferroni correction implies rescaling the significance level of α by m, where α is the desired overall alpha level and m is the number of hypotheses. Applied to the 200SME trial, the conventional α (= .005) is divided by the number of outcomes (m = 6). Hence, with the Bonferroni correction, the resulting α would be 0.0083 instead of .005. This implies, that of the two statistically significant impacts found, only the one on Design Sprint Knowledge (α=.003) would be robust to the Bonferroni correction, while the effect on Knowledge to implement Design Sprint (α=.03) would not be significant.

A.1.3 Treatment effects bounds

To further check the extent to which the above presented results are driven by the high differential attrition, lower and upper bounds for the treatment effects are estimated. This exercise consists in inputting arbitrary values to replace the missing values on the outcomes. Beyond the extreme, and perhaps unrealistic, minimum and maximum values, also more

[10] Additional information on https://egap.org/resource/10-things-to-know-about-randomization/.

realistic scenarios are computed using 25th, 50th and 75th percentiles. The values are taken separately from the control and treatment group distributions. In each scenario, controls and treated are flipped: e.g. when minimum value is imputed for controls, the maximum value is imputed for the treated. Results are available upon request. In general, this exercise shows that the results are confirmed under the most 'realistic' scenarios. More specifically, regarding the first outcome measure (General Design Knowledge), the effects would be statistically significant in the less conservative scenarios, up to the 25th percentile and weekly at the 50th percentile, then become smaller and not significant at the 75th percentile. The results on Design Sprint Knowledge (quiz) also happen to be strongly robust to this check (statistically significant up to the 75th percentile), while the positive and significant impacts on Knowledge to implement Design Sprint would hold up to the 50th percentile. The results on the remaining three outcomes confirm the insignificant effects, with the possibility of positive and significant effects on Attitudes toward Design Sprint in the 25th percentile scenario and negative effects on Desired Design Sprint adoption under the 75th percentile scenario.

A.2 DDRA Questionnaire Items

Dimension	**#**	**Question**
1. Knowledge		
1.1 General Design Knowledge *(Likert Scale)*	Q5	Please, express the extent to which you agree/disagree with the following statements: 1. I know what “User Centered Design” is 2. I would feel confident to explain to my colleagues what ”User Centered Design” is 3. I know what “Design Thinking” is 4. I would feel confident to explain to my colleagues what ”Design Thinking” is in practice 5. I know what a “Design Sprint” is 6. I would feel confident to explain to my colleagues what a ”Design Sprint” is in practice

1.2 Knowledge to implement Design Sprint *(Likert Scale)*	Q6	Please, express the extent to which you agree/disagree with the following statements: 1. I am able to define a design problem in such a way that it is easily comprehensible by people outside our company (consultants, suppliers, partners) 2. I am able to effectively managing creative ideation processes 3. I am able to take up decisions on the best design solution to implement starting from a large variety of ideas 4. I am able to pursue rapid and cheap prototyping of a design solutions (e.g. wireframing, mockups, interactive prototypes) in order to test it with users 5. I am able to set up and execute reliable user testing (the right profile and number of users) to validate those ideas/solutions
1.3 Design Sprint Knowledge *(Quiz)*	Q7	In the Design Sprint, how should the company frame the Design problem?
	Q8	How is the ideation phase done in the Design Sprint?
	Q9	How are ideas of solutions expressed and shared in the Design Sprint?
	Q10	What is a prototype in the Design Sprint?
	Q11	What is the main purpose of involving users and customers in the Design Sprint?
2. Attitudes		
2.1 Attitudes towards Design Sprint *(Score)*	Q12	How would you rank the importance of the following aspects when pursuing innovation of products or processes in your company? 1. Having a leadership with a strong vision 2. Incorporating the state-of-the-art technology 3. Creating strategic partnerships with key players 4. Using design thinking and user-centered design 5. Optimizing processes, organization and operations 6. Focusing on finance

	Q13	How much do you think each of these aspects of design thinking could benefit your company? 1. Defining a design problem in such a way that it is easily addressable by others (consultants, suppliers, partners, customers, users) 2. Effectively managing creative processes to ideate solutions to design problems 3. Taking up decisions on the most appropriate design solutions to implement, starting from a large variety of ideas 4. Pursuing rapid and cheap prototyping of a design solutions (wireframing, mockups, interactive interfaces) in order to test it as soon as possible with users 5. Setting up and execute reliable user testing (the right profile and number of users) to validate those design ideas/solutions
3. Planned actions		
3.1 Desired Design Sprint Adoption by the Company in the next 6-12 months *(Likert Scale)*	Q14	Thinking about the next 6 to 12 months, would you like that your company undertake any of the listed actions? 1. Collect feedback from users or customers with regards of your existing products in order to improve their value 2. Involve users or customers to test ideas and prototypes of new products and services (or new functionalities of existing products) 3. Hire new staff trained/experienced in design (e.g., User Experience Designer; Interaction Designer; Information Architect; User Interface Designer; Service Designer) 4. Increase the time dedicated to the design phases of new projects 5. Increase the budget dedicated to design phases of new projects 6. Hire an external User Experience design agency or freelancer to improve our capability of designing better digital products 7. Invest in user-centered design training for its employees

3.2 Expected Design Sprint Adoption by the Company in the next 6-12 months *(Likert Scale)*	Q15	To what degree do you think that in the next 6 to 12 months your company will actually undertake any of the actions listed below? 1. Collect feedback from users or customers with regards of your existing products in order to improve their value 2. Involve users or customers to test ideas and prototypes of new products and services (or new functionalities of existing products) 3. Hire new staff trained/experienced in design (e.g., User Experience Designer; Interaction Designer; Information Architect; User Interface Designer; Service Designer) 4. Increase the time dedicated to the design phases of new projects 5. Increase the budget dedicated to design phases of new projects 6. Hire an external User Experience design agency or freelancer to improve our capability of designing better digital products 7. Invest in user-centered design training for its employees

A.3 Overview of the outcome variables

		Questions				Index		Cronbach's α	
Dimension	**Measure description**	**BS**	**FUS**	**Items N.**	**Type**	**Method**	**Metric**	**BS**	**FUS**
				1. Knowledge					
1.1 General Design Knowledge	Respondent's self-perception measure of the general knowledge about i) User Centered Design, ii) Design Thinking and iii) Design Sprint	Q9	Q5	6	Likert scale	Principal Component Analysis	Normalized score, 0-10	0.905	0.906
1.2 Design Sprint Knowledge	Actual respondent's methodological knowledge of the Design Sprint	n.a.	Q7-Q11	5	Quiz	Summative Index	Normalized score, 0-10	n.a.	n.a.
1.3 Knowledge to implement Design Sprint	Respondent's self-perception of the capability to carry out a Design Sprint	Q10	Q6	5	Likert scale	Principal Component Analysis	Normalized score, 0-10	0.824	0.876
				2. Attitudes					
2.1 Attitude towards Design Sprint	Respondent's self-perception of the benefits that the company may gain in implementing the Design Sprint	Q12	Q13	5	Score	Weighted summative Index	Normalized score, 0-10	0.688	0.761
				3. Planned actions					
3.1 Desire of adoption of Design methods†	Respondent's desire of adoption in his/her company of design methods (see 1.1)	Q13	Q14	7	Likert scale	Principal Component Analysis	Normalized score, 0-10	0.774	0.791
3.2. Expectation of adoption of Design methods†	Respondent's expectation of adoption in his/her company of design methods (see 1.1)	Q14	Q15	7	Likert scale	Principal Component Analysis	Normalized score, 0-10	0.838	0.809

Notes: Dimensions 1.1 to 2.1 were measured by means of a N° items (questions) developed by the researchers. Dimensions 1.2 to 2.1 were asked at each Sprint phase. Dimensions 3.1 and 3.2 were asked by listing possible actions.

Additional notes: Cronbach's α provides a numerical value between 0 and 1, where a higher value indicates greater internal consistency. It is a measure to evaluate the reliability of a scale by measuring the extent to which all the items in the scale measure the same underlying construct: in our context it helps us to assess if the set of items or questions that constitutes our indices are consistent in their results. A high value of alpha (> 0.90) may suggest redundancies and show that the test length should be shortened.

† by the Company in the next 6-12 months