THE LOGICS OF DOUBLE PROOF IN PROOF OF CONCEPT: A DESIGN THEORY-BASED MODEL OF EXPERIMENTATION IN THE UNKNOWN

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ABSTRACT

The literature on design distinguishes between exploration-based experimentation and validation-based experimentation. This typology relies on an assumption that exploration and validation cannot and should not be performed simultaneously in the same experimentation. By contrast, some practitioners, such as les Sismo, propose that proof of concept might combine these two logics. This raises the question of what design logic might enable this type of combination of exploration and validation. We first use design theory to build an experimentation design framework. This framework highlights a typology of proof logics in experimentation related to proof of the known and proof of the unknown. Second, we show that these proof models are supported by les Sismo's cases and describe a diversity of arrangements of exploration and validation mechanisms: sequential, parallel, and combinational. Through the formalisation of proof of concept as a double proof (proof of the known and proof of the unknown), we show that proof of concept can be more than a tool for the go/no-go decision by gradually validating propositions, questioning the relevance of propositions, and discovering new propositions to be investigated and tested.

Keywords: Design theory, Design process, Process modelling, Experimentation, Proof of concept

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1 INTRODUCTION

Since its introduction in the United States aeronautics and aerospace ecosystem in the 1960s, proof of concept (PoC) has progressively become a gold standard early test step in design processes (Bendavid and Cassivi, 2012; Cooper and Sommer, 2016). In the mid-2010s, *les Sismo*, which is a French independent design studio founded in 1997, adopted this terminology and transformed it into a service offering for its clients. *Les Sismo* consists of about 20 designers who articulate the skills necessary for the creation, strategy, and realisation of humanist projects for private and public organisations. *Les Sismo* is renowned for its expertise in PoC for service and experience design in the French design community. In 2018, *les Sismo* shared that it found PoCs to be valuable not only for validation but also exploration. It declared that its PoCs identify some scientific experimentation codes, but did not state them. By contrast, it declared that its PoCs generate results richer than those from scientific experimentation, but did not explain the additional cognitive value achieved compared with scientific experimentation or the manner in which this occurred. Only snippets of additional information can be found in the literature because, to the best of our knowledge, no rigorous, systematic, and scientific research on this notion has been undertaken. The research community has interpreted the massive adoption of PoC by various actors and ecosystems in recent years as a trivial phenomenon; however, in our view, it contains an interesting research object. We believe that the success of PoC can be explained by its original ability to combine the proof of the known and proof of the unknown. Our purpose in this paper is to investigate this double nature of PoC.

2 LITERATURE REVIEW AND EXPERIMENTATION DESIGN MODELLING

2.1.1 Validation and Exploration: Beyond Negative Interference, Towards Positive Interference

The literature suggests that there are several possible forms of experimentation (see, for instance, Gillier and Lenfle, 2019). In particular, the design literature has focused on distinguishing between exploration-based experimentation and validation-based experimentation (Ben Mahmoud-Jouini and Midler, 2020; Blomkvist and Holmlid, 2011; Cross, 2008; Nicolaÿ and Lenfle, 2019, Jensen at al., 2017). These typologies reflect a good practice of the scientific method (Hacking, 1983), which recommends that researchers should first explore and then validate (Simpson, 1978). Such a sequential approach is supported by the fact that exploration and validation are identified as two mechanisms that are mutually detrimental. Exploration induces biases in the validation process and, by contrast, validation induces barriers in the discovery process (Guilford, 1957; March, 1991); that is, the literature almost systematically presents the interaction between exploration and validation as destructive, to use the language of wave theory. The massive literature that supports this thesis suggests that this case exists, but we question whether this thesis can be extended. We question whether other interaction scenarios can be considered, for example, a neutral or synergistic interaction in which the performance of the validation and exploration processes performed simultaneously is, respectively, identical to or greater than the performance of the processes performed separately. Additionally, we question whether these typologies are theoretical impossibilities or are waiting for empirical cases to be described. A peripheral part of the literature claims that other arrangements of validation and exploration is possible (Gillier and Lenfle, 2019; Löfqvist, 2009). Some literature, both old and recent, underlines the importance of the scientific method, that is, a systematic, rigorous, and organised activity as a means of discovery (Jobin et al., 2020; Lakatos, 1977; Le Châtelier, 1936; Mees and Leermakers, 1950; Perrin, 1948). However, these studies remain at the statement level and lack a rigorous framework for modelling the production of knowledge associated with the validation and exploration mechanisms. Therefore, we consider what validation and exploration mechanisms are at work in PoC, and the associated conditions.

2.1.2 Experimentation Modelling: Contributions of Statistical Theory Enriched by Design Theory

For a long time, the literature on statistical tests has clarified widely disseminated validation logic (Dagnelie, 2000; Emmert-Streib and Dehmer, 2019; Neyman et al., 1933). This logic contains a design hypothesis: we can design at least one unit, and identify and measure some of its characteristics, called variables. Statistical test theory presupposes, more broadly, an intrinsic design activity (e.g., hypothesis design) and sometimes requires design effort when available tools are not appropriate (e.g.,

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a new observation instrument), but suggests that these elements are given. Moreover, in the test theory framework, the knowledge bases on which the experimentation rely also remain largely implicit. A clarification study could better underline the gap between what was known and unknown before and after experimentation and therefore trace the accumulation or expansion of knowledge. More generally, it could also provide a better understanding of both what happens during experimentation and the results obtained, particularly when they are not as expected. The latest advances in design theory (Le Masson et al., 2017; Hatchuel et al., 2018) may contribute to this explication effort, and integrate and complete the experimentation modelling provided by test theory and Thomke (2003). Concept-knowledge (C-K) theory (Hatchuel and Weil, 2009) was chosen for formalising a general framework to monitor the reasoning mechanisms of exploration and validation in experimentation (Hatchuel et al., 2013) because of its most advanced ability to account for the generativity of a design process (Hatchuel et al., 2011; Hatchuel et al., 2018). C-K theory models the design process through the dual expansion of the concept space and knowledge space. Knowledge (K) is a logical proposition that can be assessed as true or false. A concept (C) is a desirable proposition that has no logical status in the existing knowledge space (i.e., neither true nor false).

2.1.3 Proposal for a General Framework of Experimentation Design based on C-K Theory

The general framework in Figure 1is based on the following notation. The initial concept is characterised by a partially unknown entity (*X*), which verifies a set of properties (*P*), for instance, "common spaces that re-enchant the customer". The expansion of the concept space is performed through the generation of a set of properties (*Pi*), for instance, "by improving check-in", $i = 1,\ldots, n$ and $j = 2,\ldots, n$.

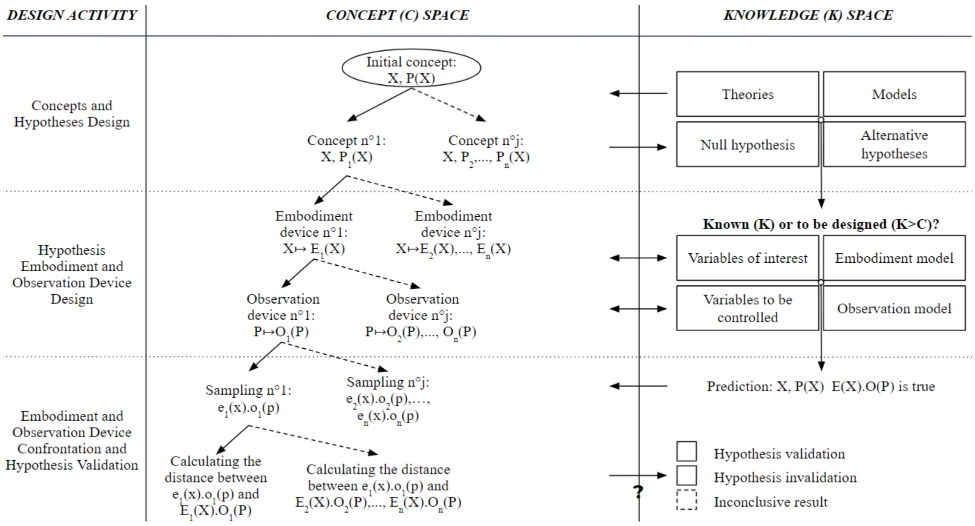

Figure 1: General framework of experimentation design based on C-K theory

3 METHODOLOGY

3.1 Research Approach

Based on this general framework of experimentation design, we highlight three typologies of learning mechanisms associated with proof models. We call these proof models proof of the known, proof of the known and proof of an independent unknown, and proof of the known and proof of a dependent unknown. For each of these models, we attempt to identify these learning mechanisms in PoC cases conducted by *les Sismo*. We selected five cases of *les Sismo*'s PoC following theoretical sampling. In a sense, we chose them for their ability to illustrate the three proof models and not for their potential for generalisation or representativity (Eisenhardt and Graebner, 2007).

3.2 Data Collection and Analysis

The data collection was performed as part of an intervention research study (Hatchuel and David, 2008; Radaelli et al., 2012) conducted by the authors from October 2018 at *les Sismo*. We use five client project cases to illustrate the proof models: one to illustrate the mechanism of the proof of the known (Illustration 1.1), two to illustrate the mechanism of the proof of the known and proof of an

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independent unknown (Illustrations 2.1 and 2.2), and two to illustrate the mechanism of the proof of the known and proof of a dependent unknown (Illustrations 3.1 and 3.2). Regarding Illustrations 1.1, 2.1, 2.2, and 3.1, PoC took place between February 2016 and October 2017. Data collection for retrospective analysis was performed between October 2018 and April 2019 through formal and informal interviews with project managers and co-founders. These data were triangulated and supplemented by information from working documents and project deliverables found in *les Sismo*'s digital archives. For Illustration 3.2, a longitudinal study (Åhlström, and Karlsson, 2016) was conducted by the first author between November 2018 to April 2019. The design of the PoC started in December 2018 and PoC took place in March 2019. Given that the launch of the project was in January 2018, interviews with members of the project team were conducted and information was collected from internal documents (e.g., working documents, minutes of meetings with clients, and deliverables) prior to November 2018. The data from November 2018 was collected through frequent participation in working sessions with the project team or in pairs with the project manager, active participation during the two days of testing, and follow-up on the elaboration of restitution and list of recommendations. For each illustration, we used the same description structure based on the general framework proposed: concept and hypothesis design, hypothesis embodiment and observation device design, embodiment and observation device confrontation and hypothesis validation, and outcomes.

4 THREE PROOF MODELS AND ASSOCIATED ILLUSTRATIONS

4.1 Type 1: Proof of the Known

4.1.1 Reasoning Mechanism 1

This first proof model describes experimentation for which the learning process is limited to the validation or invalidation of a set of hypotheses, for example, performing an operation from the C space to the K space, that is, a conjunction in the terms of C-K theory. The reasoning mechanisms of this type of experimentation are the very essence of a statistical test. Test theory foresees two possible outcomes, that is, the rejection of the null hypothesis in favour of the alternative hypothesis or the rejection of the alternative hypothesis in favour of the null hypothesis, that produce an extension or sophistication of theories and models. Moreover, there is a third transitory case in which the test is inconclusive, that is, sometimes the data tend towards the null hypothesis validation and sometimes the data tend towards the alternative hypothesis validation. This case requires the designer/experimenter to verify its experimental design, and if necessary, use the identification of a new variable to revise its experimental design to conduct a better controlled experimental process in the hope of validating the hypothesis. This proof model relies on sequential logic: exploration and then validation.

4.1.2 Illustration 1.1

Concept and hypothesis design. The client organisation was a French hotel chain that offers short- and medium-term rental apartments in cities. In the mid-2010s, the organisation was challenged by new protean competition and changing consumption patterns. In this context, the organisation initiated several projects, such as the renovation of its aparthotels. Unfortunately, this massive investment did not result in significant improvement in the opinion and brand identification of its clients. In 2016, the brief delivered to *les Sismo* was to help the organisation to transform common spaces to re-enchant customers. *Les Sismo* started its mission by conducting observations and interviews in the common areas of a hotel (e.g., corridors, lifts, parking, and rubbish bin area). It conducted an observation relevant to an inquiry in the rubbish bin area. Indeed, it observed that almost-new objects were abandoned next to the rubbish bins. By pushing the investigation with employees, *les Sismo* learned that this observation was not an isolated case, and a large number of clients stayed for several months for professional reasons. These professional customers enjoyed customising their apartments with accessories (e.g., cushions, curtains, small furniture, and frames). *Les Sismo* proposed an object library in the hotel lobby containing items that clients could borrow free of charge and without a time limit simply by notifying an employee. These objects would allow clients to customise or equip their apartment to make their stay more pleasant. The project sponsors were resistant to this idea because they feared that the items would be stolen. The project sponsors finally conceded that they should not automatically dismiss the concept based on this hypothesis, but the hypothesis had to be validated using field experimentation. **Hypothesis embodiment and observation device design.** *Les Sismo*

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bought and installed a library containing about 20 items (e.g., lamps, frames, mirrors, fitness weights, and cushions) in the lobby of a hotel in the chain. The service was promoted at the reception desk and through a sign on the library stating "items to borrow for personalising your apartment". The PoC lasted six months. The objects were tracked during the six months by the receptionists using a very simple and low-cost system. Each item was labelled with a code (three letters and two digits) and referenced in an Excel spreadsheet. When a client wanted to borrow an item, a receptionist retrieved the associated code and registered it in the Excel spreadsheet. The receptionists regularly compared the library inventory and the data in the Excel spreadsheet. *Les Sismo* conducted observations and interviews during the first week to survey the client experience in relation to the object library. **Embodiment and observation device confrontation and hypothesis validation.** During the test period, no theft was reported, to the great surprise of the client sponsors, which allowed *les Sismo* to invalidate the client's hypothesis. The original evaluation setup enabled the observation of a phenomenon that was even further from the sponsors' view of their clients: the receptionists tracked an increase in the quantity of objects through the contributions of some clients. **Outcomes.** The PoC allowed *les Sismo* to invalidate the client's hypothesis and validate its own hypothesis. The PoC permitted the validation of the desirability and viability of the concept. At the end of the PoC, the test establishment decided to integrate the object library in a sustainable manner in terms of both the content and logistics. At the end of 2020, two-thirds of the aparthotel network implemented the object library, which represents about 80 establishments.

4.2 Type 2: Proof of the Known and Proof of an Independent Unknown

4.2.1 Reasoning Mechanism 2

This second proof model describes experimentation that not only allows hypothesis validation but also reveals unknown peripheral variables, that is, variables that do not have a direct impact on the outcome of the hypothesis validation. Such a discovery requires the prior design of an extended observation device and model to enable this capture, and clarification of knowledge bases to enable its recognition as a novelty. In this proof model, validation and exploration are performed in parallel. The exploration mechanism relies on the validation mechanism, but does not interfere with it. The designer/experimenter takes advantage of the experimental scenario to explore the periphery.

4.2.2 Illustration 2.1

Concept and hypothesis design. The client organisation was a major European hotel group that faced similar challenges to those presented in the previous illustration. The group asked *les Sismo* to help it to reinvent the hosting experience in one of its hotel brands to attract new customers, particularly Millennials. The inspiration phase highlighted that Millennials want to save money, even if it means more work for them. The ideation phase gave rise to the hypothesis that a collaborative economy could be implemented by asking clients to perform certain tasks in return for economic savings. *Les Sismo* wanted to test what tasks customers were willing to perform and how they wanted to be rewarded. **Hypothesis embodiment and observation device design.** For a few days, the clients of a hotel in the chain were offered the possibility of undertaking some tasks (e.g., make the bed, vacuum, wash windows, and carry out small repairs) in exchange for a €5 voucher that could be used in a selection of shops nationally. Tasks were calibrated to last no more than 30 minutes and did not require training. Each task had a checklist and the required items or tools. These kits evolved during the week. The hotel's employees were responsible for explaining the test, in addition to the promotion of daily tasks, checking each accomplished task, and rewarding clients. During the test week, there was a follow-up of the tasks performed by clients and the discount vouchers provided. In a complementary manner, *les Sismo* conducted observations and interviews with clients and employees. It investigated why the clients were more willing to perform some tasks, and their motivation. **Embodiment and observation device confrontation and hypothesis validation.** Twenty vouchers were given away in a holistic manner. Only "basic" and "self-contained" tasks were performed. Indeed, clients only performed tasks they were familiar with and did not perform tasks that could have an impact on someone other than themselves. One guest vacuumed a corridor, but every other task (small repairs, painting jobs, and window washing) remained undone. Regarding the possibility of making a bed, 90% of clients took the sheets and accepted making their beds and 50% declared that they would have done this without a reduction. *Les Sismo* learned that people accepted making their beds to ensure that it was done according to their expectations

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and, above all, to control the cleanliness of the mattress. **Outcomes.** The PoC clarified the field of validity of the concept relative to the possibility of the client performing certain tasks in exchange for a reduction. Furthermore, the PoC revealed a peripheral variable: the importance to the client of easily checking the cleanliness of the mattress.

4.2.3 Illustration 2.2

Concept and hypothesis design. The client organisation was a state agency in charge of employment. Its role is to compensate job seekers and guide them back to work, and to guide companies in their recruitment. In connection with its strategic plan for 2020, the organisation developed a new digital pathway for job seekers that was a great success. The agency wanted to replicate this success in the physical pathway of job seekers. Therefore, the agency launched a consultation in 2016 to obtain help with the development of a new agency model for its 1,000 local offices across the country. This consultation was won by *les Sismo*. Based on the inspiration phase conducted by *les Sismo*, a work axis emerged about a warmer and more reassuring welcome, and gave rise to a co-creation workshop dedicated to this theme. Propositions were made about furniture, decoration, space design, posture, and speech. *Les Sismo* formulated the hypothesis that meetings between counsellors and job seekers would be warmer if they were side by side rather than face to face. When *les Sismo* began to survey the employees, strong reactions emerged from some counsellors who categorically refused this new posture. As the discussion progressed, *les Sismo* understood that there were two types of meetings. The first type was dedicated to guiding the job seeker on his/her way back to work. The second type was dedicated to the discussion of financial support. This type of meeting was sometimes difficult, particularly regarding overpayments. It was not uncommon for the tone to rise and the job seeker to become aggressive. The side-by-side posture was therefore a source of fear for counsellors who had regularly experienced this type of scenario. The traditional desk and face-to-face posture had the merit of creating a safe distance. **Hypothesis embodiment and observation device design.** These first interviews helped *les Sismo* to narrow the test sample. The PoC was conducted only for the first type of meeting in a voluntary agency for one week. The advisory areas were equipped with tables of different shapes (rectangular, square, and round) to test new postures. Two types of seats were installed around this table: a fixed seat for the job seeker and a mobile seat for the advisor, which allowed him/her to choose a position around the table. To facilitate the different types of positions during the interview, the advisors were equipped with portable computers. During the test week, *les Sismo* conducted observations of meetings between advisors and job seekers when possible, and interviewed them both to evaluate the advantages and disadvantages of each table shape. The criteria covered the exchange quality, screen sharing, freedom of movement, position ergonomics, and feeling of security. The last criterion was added following preliminary discussions. **Embodiment and observation device confrontation and hypothesis validation.** The PoC generated information on the effects of this new posture; both positive (enhancement of human contact, apprehension reduced by conviviality, pleasant and peaceful environment for all, and dynamic and pedagogical posture) and negative (delicate proximity to difficult people, lack of ergonomics and practicality because of the table legs, and nuisance caused by the open architecture). A very interesting critical variable was indicated by advisors: the sound level. Being closer naturally invited job seekers to speak less loudly, which tended to reduce aggression and therefore, create a climate of confidence and serenity. **Outcomes.** The PoC allowed not only the validation of a new posture and the furniture characteristics that could promote and ease it, but also the identification of an unknown peripheral variable, which was the sound level.

4.3 Type 3: Proof of the Known and Proof of a Dependent Unknown

4.3.1 Reasoning Mechanism 3

This third proof model describes experimentation that reveals unknown variables that play a significant role in the outcome of hypothesis validation through invalidation or inconclusiveness. In the sense of test theory, it describes the identification of an unknown moderating variable, that is, a variable that changes the strength or direction of the effect between the two variables of interest. Such a discovery requires extended prior exploration (e.g., alternative hypotheses, embodiment and observation devices and models, and sampling) to enable the unknown variable to be captured. The discovery forces the designer/experimenter to clarify the validity conditions of the theory or model on which the hypotheses are based. This new known variable may be seen as an additional variable to be controlled or measured

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in future experimentation or as a source of innovation. This new known variable forces the designer/ experimenter to revise knowledge previously considered as established, that is, a K-reordering; and design undecidable hypotheses, models, and theories, that is, perform an operation from the K space to the C space, that is, a disjunction in the terms of C-K theory. In this proof model, validation and exploration are combined, and both mechanisms positively interfere with each other.

4.3.2 Illustration 3.1

Concept and hypothesis design. The client organisation was a cooperative supermarket chain. An internal innovative challenge underlined the issue that it was difficult for some customers (e.g., older adults and frail people) to carry heavy items, and raised the idea of developing a new service to offer support to customers with heavy loads. *Les Sismo* was asked by the headquarters of the organisation to prototype and test the concept in 2016. The service concept can be divided into three main steps: scanning the labels of the heavy items using the supermarket's mobile application, presenting the barcodes in the mobile to the cashier for scanning, and collecting the heavy items at the supermarket's drive-through. The client organisation and *les Sismo* hypothesised that customers wanted this service to secure the development of the mobile application and its associated logistics. **Hypothesis embodiment and observation device design.** The service concept was prototyped without the mobile application and implemented during five days at a supermarket in the chain. Service prototyping and delivery required few technical and human resources. The labels of 30 selected items were printed and positioned near the price tag using basic plastic supports. Customers who wanted support to carry these items could pick up the labels and present them to the cashier. The cashier then informed *les Sismo* representatives, who were wearing T-shirts flocked with the logo of the service concept and wings, who collected the items from the supermarket shelves. They transported the items to the drive-through via roller bins that the supermarket already had and put the items in the boot of the customer's car. For five days, *les Sismo* conducted observations and interviews with the supermarket's customers. The first hours and days were very disappointing, to the great surprise of the client organisation and *les Sismo*, because few people used the service. *Les Sismo* was so persuaded of the relevance of the concept that it made adjustments throughout the week. For example, it tried to improve communication about the service by increasing the service promotion devices and contact points (e.g., on the shopping trolley and at the supermarket's reception desk). **Embodiment and observation device confrontation and hypothesis validation.** The PoC generated a first key piece of information that could have probably been identified by a prior observation step. When fragile people plan to purchase heavy items that they buy exceptionally (e.g., a bag of barbecue charcoal), they come with a relative, and the shopping session almost becomes an excuse to have company. This learning pushed *les Sismo* to refocus on items that people bought more regularly (pack of water or milk). The PoC generated a second key piece of information that derived from a strange observation. *Les Sismo* observed an older adult who came to the supermarket at the beginning of the week and strongly refused the service. The same older adult came back a few days later and begged for the service. *Les Sismo* associated this reversal with the presence and absence of his wife on his first and second visits, respectively. *Les Sismo* understood that the customer wanted, with a certain amount of pride, to show his wife that he was still able to carry heavy loads. Similarly, one parent shopping with a child did not tend to accept the service, although it was free of charge. Although the service added an additional step in the parent's journey (a stop at the withdrawal zone), the refusal was more related to the fact that the parent wanted to show that he/she was doing well on his/her own. Once the self-esteem variable was discovered, it helped *les Sismo* to clarify the following incomprehensible results: people who seemed to be in good shape used the service, whereas people who seemed to be vulnerable refused the service. Indeed, this provided an explanation of why people generally refused or accepted the service. People with good self-esteem tended to accept the service, whereas people with poor self-esteem viewed the service as disturbingly highlighting their vulnerability and therefore tended not to accept the service. **Outcomes.** The PoC allowed an invalidation of the concept for the initial target and, in that sense, led the client organisation to abandon the project while the investment in the project was very low. By contrast, the PoC allowed the identification of a critical variable (self-esteem of the customer), which interfered with the test and caused some clients to decline the service.

4.3.3 Illustration 3.2

Concept and hypothesis design. The client organisation was a global leader in urban mobility that develops, operates, maintains, and modernises innovative public transport systems. One of the goals

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reported in its strategic plan for 2025 was to place the travelling experience at the heart of its actions. In connection with this ambition, the client organisation launched a call for tender at the end of 2017 to find help to rethink the traveller's experience at the level of its information and sales areas, which take the form of a traditional counter. *Les Sismo* won this call for tender. The inspiration and ideation phase led *les Sismo* to formulate a hypothesis. It believed that the traveller's experience could be improved by the agent having a warmer posture, and that this new posture could be promoted by a new configuration of the counter furniture and area (in the same vein as Illustration 2.2). **Hypothesis embodiment and observation device design.** Two configurations with different degrees of opening were prototyped. One of the configurations was embodied by a triangular counter with a completely open counter space and no difference in floor height compared with the remainder of the space. The prototyped counter furniture and area were installed during one day in a large network station in a reformed space. Another counter located nearby was closed to maximise the flow of travellers to the test area. A volunteer employee was seconded from his position to participate in the test. Before taking up the position, he was quickly briefed about the actions he could perform in the context of the test (e.g., he could only sell metro tickets). The issue related to queue management had already been identified, and to investigate this issue, different devices were added for the test (e.g., belt barriers) and different configurations were tested. Three designers were dedicated to the observation of the behaviour of travellers and employees during the day of the test of this second configuration. They had different viewpoints of the test area and station. They interviewed volunteer travellers in the station who either tested or did not test the new experience. **Embodiment and observation device confrontation and hypothesis validation.** Regarding the hypothesis that the traveller's experience would be improved by giving the agent more freedom of movement, the test data were inconclusive. Travellers perceived the agent to be more dynamic and available in general with this new configuration. However, this new configuration induced agent behaviour that *les Sismo* had imagined, but not its consequences. The agent tended to move away more or less strongly from the counter space to better advise travellers. Returning to the perimeter close to the counter was not a reflex for the agent, but he continued to keep the counter in sight. He only returned to the counter area if someone started to wait there. The issue is that this counter configuration was so disruptive that few people understood that if they waited in this test area an agent would come soon. By contrast, on the way back, the agent was often intercepted by travellers, which created competition and therefore tension for travellers who were still waiting wisely near the counter. *Les Sismo* had thought about the problem of queue management at the counter level, but not at the station level. As queue management was already an observation criterion and because of *les Sismo*'s observation model and device, *les Sismo* quickly became aware of this issue. It made this knowledge a lever for creating value through the creation of a new post: a "mobile agent" who was not associated with a counter and could provide an additional service in the station. This new position could limit the pitfall observed because the agent could pass the baton to the mobile agent if the advice required great mobility. **Outcomes.** The PoC clarified the area of validity of the concept: the PoC showed the relevance of opening the counter, but not too much. Indeed, the other configuration tested that was semi-open was more appreciated by travellers and agents. Finally, the PoC revealed the interdependence between agent mobility and queue management, and generated new creative ideas.

5 CONCLUSION AND DISCUSSION

In this paper, we investigated the question of what design logic might enable the combination of exploration and validation in proof of concept. We first used design theory to build an experimentation design framework. This framework highlighted a typology of proof logics in experimentation related to proof of the known and proof of the unknown. The key characteristics of these proof models are presented in Table 1. Furthermore, we found that the initial experimentation design influenced the type of proof models that could be achieved. If a minimum experimentation design was required to validate the hypothesis (proof of the known), additional design activity had to be performed to enable the proof of the unknown (e.g., extending the observation model and formulating a variety of hypotheses). The search for proof of the known is a necessary but insufficient condition for proof of the unknown. The more the designer/experimenter systematically explains the design alternatives and the associated knowledge (expansion), the more new concepts and knowledge will be generated.

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Table 1. Key characteristics of the three proof models

Proof Typology	**Arrangement of Exploration and Validation Mechanisms**	**How Knowledge was Proved**	**How the Concept was Proved**
Proof of the known	Sequential: exploration then validation	Extension/sophistication of theories and models	N/A
Proof of the known and proof of an independent unknown	Parallel: experimentation is an opportunity for peripheral exploration	Extension/sophistication of theories and models	Identification of, for example, unknown peripheral variables and hypotheses
Proof of the known and proof of a dependent unknown	Combinatorial: validation and exploration synergistically interfere	Reconsideration of, for example, variables, hypotheses, models, and theories	Regeneration of, for example, variables, hypotheses, models, and theories

Second, we succeeded in identifying the three logics in PoC cases conducted by *les Sismo* that were used in this paper as illustrations of the proof models. Experimentation design modelling and proof of the known support why *les Sismo* felt that its PoC followed scientific reasoning. The mechanism for the proof of the known was found in both scientific experimentation and *les Sismo*'s PoC. Moreover, the clarification of the three proof models provided a better understanding of how PoC can sometimes do more than a statistical test, which is a gold standard for scientific experimentation that focuses only on the proof of the known. In this sense, the PoC may have generative properties superior to scientific experimentation. However, the reverse may also be true if the PoC is not well designed and conducted; the proof of the known can therefore be reduced or aborted, and consequently, similarly for the proof of the unknown. The mechanisms highlight the difficulty in managing the PoC. Indeed, many dimensions are mixed: some are related to the concept space and others to the knowledge space, and often associated with very varied bases of knowledge. Strong expertise is therefore needed to avoid falling back into the paradigm of a negative interaction between exploration and validation. Work remains to be done to investigate the most appropriate context for each of the three logics and explain further the differences between design activities regarding them. We used different client case studies to illustrate the three mechanisms, but further work should show that they are compatible, that is, these three mechanisms can be found in the same PoC, but this makes PoC management even more complex.

Finally, the modelling of the PoC as a double proof, that is, proof of the known and proof of the unknown, enriches the unique representation of PoC as a tool for the go/no-go decision (Bendavid and Cassivi, 2012; Cooper and Sommer, 2016). Indeed, beyond being a milestone in the design process, PoCs can help with structuring the design process that must deal with the complex process of accumulation of knowledge and rediscussion of certain knowledge, similar to experimentation in the unknown. The mechanisms associated with the double proof provide a better understanding of how PoCs can gradually validate dimensions, question the relevance of dimensions, and discover new dimensions to be tested.

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