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GENERATING PROSPECTIVE SCENARIOS OF USE IN INNOVATION PROJECTS

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RÉSUMÉ

CONSTRUIRE DES SCÉNARIOS D'USAGE PROSPECTIFS DANS LES PROJETS D'INNOVATION

L'ergonomie prospective est une modalité d'intervention ergonomique centrée sur l'anticipation des besoins et activités futurs, visant à assister les premières étapes du processus de conception innovante centrée utilisateurs. À ce jour, peu de propositions méthodologiques ont été formulées pour assister les interventions en ergonomie prospective, bien que ceci constitue un levier majeur pour une meilleure intégration de la conception centrée utilisateurs dans les projets d'innovation. Ainsi, les méthodes classiques de l'analyse des usages sont d'un intérêt limité lorsque le concepteur doit travailler avec des concepts de produit mal définis, car il peut s'avérer difficile de décrire les usages futurs du produit en question. Dans cet article, nous proposons que certaines méthodes de créativité, souvent utilisées pour résoudre des problèmes de nature technique dans le cadre de projets de conception, puissent être utilisées pour élaborer des scénarios spéculatifs portant sur l'usage futur d'un produit. Nous avons réalisé des simulations de réunions de conception portant sur l'anticipation des usages de différents produits et avons évalué, au travers de deux études, les effets de méthodes empruntées à deux paradigmes de créativité sur la capacité d'une équipe pluridisciplinaire de conception à formuler des scénarios d'usage futurs.

La première étude visait à évaluer les apports de méthodes empruntées au paradigme du Creative Problem Solving (CPS) – le brainwriting et la matrice de découvertes – à la production de scénarios prospectifs d'usages. Elle fait suite à une étude qui montrait que ces méthodes n'avaient pas d'effet sur le nombre de scénarios produits ni sur le nombre d'idées relatives aux usagers futurs du produit ou à leurs activités. Nous montrons ici, cependant, que ces méthodes permettent de mieux structurer la dynamique d'exploration de l'espace créatif, et d'aboutir à des idées plus originales.

Dans la seconde étude, nous avons examiné la capacité d'une équipe de concepteurs à exploiter l'analyse multi-écrans – une méthode empruntée à la théorie de résolution des problèmes inventifs (TRIZ) – pour construire un discours sur les usages futurs d'un produit innovant. Les résultats suggèrent que

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l'équipe était en mesure d'anticiper des évolutions de l'artefact technique – ce qui correspond à la finalité initiale de la méthode – mais pas de se réapproprier l'outil pour imaginer des scénarios illustrant les usages futurs possibles du produit. Nous décrivons enfin les conséquences de ces résultats pour élaborer de nouvelles méthodologies d'intervention en ergonomie prospective.

Mots-clés : *Ergonomie prospective, innovation, design conceptuel, conception par scénarios, créativité*

I. INTRODUCTION

Prospective Ergonomics has been defined as "*the part of ergonomics that attempts to anticipate human needs and activities so as to create new artefacts that will be useful and provide a positive user experience*" (Robert & Brangier, 2009, 2012). It has been argued that the development of prospective ergonomics methods constitutes a major milestone for the discipline of ergonomics, and that this should allow ergonomics to respond more efficiently to the challenges of innovation design (Nelson, 2011; Liem & Brangier, 2012).

In this paper, our goal is to contribute to this body of research by presenting a methodological proposal to assist the generation of prospective scenarios of use in the early stages of innovative product design. We begin by offering a review of the literature in the section below. The current interest in Prospective Ergonomics is related to an increased focus on the anticipation of future product use and to the redefinition of product use as an object of creative design. We argue that creativity tools, such as those commonly used in innovation design, can help designers generate and examine scenarios of future use for innovative design. We introduce two creativity paradigms, from which were drawn the specific tools we propose to use to assist the generation of prospective scenarios. In section 3, we present our methodological proposal in detail. Two experiments, aiming to validate this proposal, are reported in sections 4 and 5 respectively. The framework and experiments presented in this paper follow our recent work in the field of prospective ergonomics (Nelson, Buisine, & Aoussat, 2012). We end the paper by discussing the results obtained and their relevance to research and practice in ergonomics.

II. LITERATURE REVIEW

II. 1. From User-Centered Design to Product/Use Codesign

Two reasons have motivated the recent surge of interest in Prospective Ergonomics as a research topic. The first of these is the increasing acknowledgement that ergonomics should assist businesses at a strategic level (Dul et al., 2012). However, it has also been pointed out that the term "strategy" can have multiple meanings. Two of these meanings are particularly interesting to us: strategy can refer to a *position*, or to a *plan* (Dul & Neumann, 2009). According to the principle of iterative design and prototyping (e.g. in the ISO 9241-210 standard), understanding and specifying the context of use should provide designers with means (a) to produce design solutions that satisfy user requirements, and (b) to assess whether these solutions satisfy these requirements. The proposal of new, user-relevant products relies on the prior existence of situations to be used as a reference for activity analysis (Daniellou, 1992). It is expected that by analysing these existing situations and simulating future situations, ergonomists can provide descriptions of "possible future activities" whose goal is both to support and to question design by negotiating the terms of the future activities of human operators (Daniellou, 2007).

Simulation-based approaches have enjoyed considerable success in the ergonomic design of work systems, extending recently to organizational design (van Belleghem, 2012). However, a number of authors have recently argued that this approach does not respond adequately to the requirements of innovative product design, particularly in the case of "technology-push" design projects (Brangier & Bastien, 2006; Nelson, Buisine, & Aoussat, 2013). Indeed, the assumption that the "end users" of a product are clearly identified in the early stages of the design process is not always verified. At the heart of this issue is the fact that firms must deal with three conflicting requirements when involved in innovation projects: (*a)* they need to innovate repeatedly and regularly in order to maintain a market position (Hatchuel, Le Masson, & Weil, 2002); (*b*) they need to develop new technological know-how, either to renew or to strengthen their core competencies (Leonard-Barton, 1992); and (c) as highlighted in the UCD (User Centered Design) literature, they need to propose products that respond adequately to user needs and requirements (Maguire, 2001). Veyrat (2008) argues that in order to face these conflicting requirements, design practices have evolved towards greater integration, termed "Product/Use Codesign": "*Innovation constitutes a place where technological exploration and the design of use are negotiated simultaneously*" (Veyrat, 2008, p. 101, our translation).

II. 2. Towards a shift to prospective scenarios of use

The shift to "Product/Use Codesign" switches the emphasis of UCD from the analysis of existing activities to the anticipation of future sources of user value. The goal of this anticipation is twofold: to anticipate change, and to provoke it. These are also the stated goals of prospective analysis (Godet, 2007). Furthermore, prospective analysis also commonly relies on scenarios to describe future events. Scenarios are intended to assist decision-making at three main stages in the design process (Rosson & Carroll, 2002): *(a)* the analysis of problem situations in the start of the process, *(b)* the generation of design solutions at various levels of complexity, and *(c)* the evaluation of these design decisions according to UCD criteria. It can be noted, however, that the role of scenarios has evolved in recent years, mirroring the evolutions outlined in section II.1: scenarios are intended both to anticipate change and to provoke it. Depending on what stage of the design process they are introduced in, the balance between these two goals may not be the same. In the early stages of design, the goal is to provoke change, *i.e.* the start of an innovation design process within a strong UCD framework. In the later stages, the goal is to anticipate change in order to steer detailed design decisions based on their likely effects on future user activity. Thus, it can be argued that the purpose of scenarios in the early stages of design is not only to provide an accurate vision of future user activity, but also to crystallize designers' current knowledge and assumptions about future activity. Thus, from this point of view, scenarios of future use in prospective ergonomics are not just a material for analysis, but also a product of creative design.

II. 3. Choosing creativity tools to generate prospective scenarios of use

Creativity has been described as the capacity to produce something that is both novel and suited to the context of the task (Bonnardel, 2009). Three main creativity paradigms have been identified to help designers achieve this (Cavallucci, 1999): (*a*) creativity as an art that only a chosen few can perform; (*b*) creativity as a balance between the creative (*i.e.* idea-generating) and judicial (*i.e.* idea-selecting) mind; and (*c*) creativity as the result of the systematic application of problem-solving rules. In this section, we focus on the two latter positions, and describe the two paradigms that exemplify them – Creative Problem Solving (CPS), and the Theory of Inventive Problem-Solving (TRIZ). Both these paradigms will serve as a source for our methodological proposal.

II. 3. 1. Creative Problem-Solving (CPS)

One approach to improve creative performance was proposed by Osborn (1957) who termed it "Creative Problem Solving" or CPS. The CPS process model comprises three main elements: understanding the problem, generating ideas, and planning for action. Much of CPS research focuses on the second stage. Indeed, Osborn's work on brainstorming puts the emphasis on improving *ideational fluency*, *i.e.* the number of ideas generated in response to a problem. Osborn advocated the use of the following rules to improve ideational fluency: (*1*) Criticism is ruled out; (*2*) Freewheeling is welcomed; (*3*) Quantity is wanted; and (*4*) Combinations and improvements are sought. Osborn made numerous claims about the effectiveness of his brainstorming procedure. Initial studies gave support to at least some of his claims (e.g. Parnes & Meadow, 1959). Further work (Diehl & Stroebe, 1987) identified a phenomenon known as "production blocking"– the observation that, contrary to expectations, nominal brainstorming groups (*i.e.* individual brainstormers whose ideas are pooled) consistently outperform interactive brainstorming groups. Paulus (2000) noted that numerous cognitive and social factors have been found to positively or negatively impact idea generation (Table 1), leading to new idea generation techniques being derived from Osborn's initial proposal. Brainwriting, used in this paper, is one of these methods. It suggests that brainstorming groups should express their ideas not in speech but in writing. This is expected (1) to encourage participation by increasing accountability in idea generation (participants typically use different color pens to mark authorship), and (2) to lower the risk of production blocking by eliminating the need for turn-taking in oral communication (Paulus & Yang, 2000).

TABLEAU 1. *Facteurs cognitifs et sociaux stimulant et inhibant la créativité dans des tâches de génération d'idées en groupe (adapté de Paulus, 2000)*

Table 1. Cognitive and social factors stimulating and inhibiting creativity in group idea generation tasks (adapted from Paulus, 2000)

	Cognitive factors	**Social factors**
Stimulation	– Confrontation of complementary and heterogeneous points of view – Idea generation through free association of concepts – Confrontation of various cognitive styles	– Effects of competition and accountability in idea generation – Goal-setting practices
Inhibition	– Production blocking, forgetfulness – Non task-related behavior – High mental workload	– Anxiety and downward comparison – Social loafing and freeriding – False impression of one's idea generation productivity

II. 3. 2. The Theory of Inventive Problem-Solving (TRIZ)

TRIZ defines inventive problems as "*technical problems for which at least one critical step to a solution as well as the solution itself is unknown*" (Savransky, 2000, p. 4). A major source of difficulty in solving inventive problems is a phenomenon known as *psychological inertia* (Altshuller, 1996). This concept highlights the fact that designers' reasoning is limited by their own knowledge and by their assumptions related both to the problem and to what constitutes the set of acceptable solutions. This often prevents designers from identifying the optimal solution to a problem. TRIZ proposes a number of tools intended to direct designers towards new and appropriate solutions, to signal the most promising strategies, and to provide access to important, well-organized and necessary information at every step of the problem-solving process.

The multi-screen approach (Altshuller, 1996) is one of the tools proposed in the TRIZ framework that can be used to achieve this. It uses an artifact, a set of screens, to structure the identification of trends in technological evolution, and to define key issues for technological innovation. These screens allow the solver to follow two basic principles. First, the designer follows what Savransky (2000) calls "*systems thinking*". Instead of focusing only on the system to design, systems thinking focuses on an organizational hierarchy covering three main levels of analysis: 1) the *super-system*, or environment which the technology belongs to, *e.g.* an airspace populated by many aircrafts; 2) the *system* to be designed, *e.g.* a single airplane; and 3) the subsystems, or elementary components of the system, *e.g.* the physical elements related to the major technical functions in the plane. Second, technical systems are considered as the products of a process of technological evolution: the multi-screen analysis seeks to follow a dynamic approach which takes into account the past and future of the system that is to be designed. In its simplest form - which we will use here - the multi-screen approach uses a matrix of nine screens (Figure 1), although more screens can be used in order to refine the search for ideas.

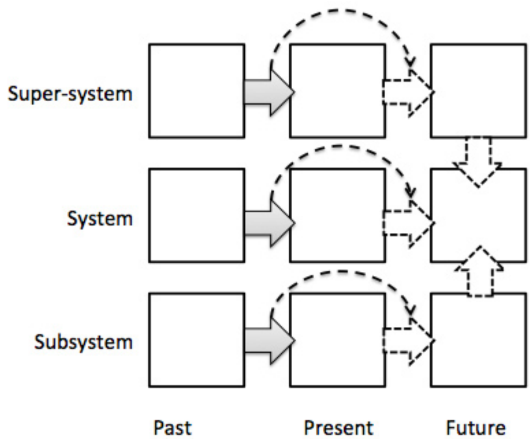

Figure 1 – Diagramme des neuf écrans (adapté d'Altshuller, 1996). Cette version (Durand, Weite, Gazo, & Lutz, 2007) met en avant le rôle des transitions entre écrans dans les situations de conception innovante. Les flèches en pointillés indiquent les emplacements où les concepteurs sont amenés à anticiper des tendances futures et leurs effets sur l'identité du système futur.

Figure 1– Nine-screen diagram (adapted from Altshuller, 1996).
This version (Durand, Weite, Gazo, & Lutz, 2007) highlights the role of transitions between screens in innovation design. Dashed arrows indicate the transitions where designers anticipate future trends and their effects on the identity of the future system.

In its classical use, the multi-screen diagram makes it possible to identify issues in existing systems, and to frame them in terms of *contradictions* related to its characteristics (Altshuller, 1996). For example, one might say: "*our new airplane needs a more powerful engine to carry more passengers, but a heavier engine will slow the plane down*". By using the multi-screen approach, designers are able to produce a model of the ideal solution that they should try to reach to solve these contradictions. This ideal solution is based on identifying existing trends that lead evolutions in technology and use practices, and extrapolating from these trends to identify desirable characteristics for future products. We believe this is a promising approach to help designers anticipate the use of innovative products. However, the primary scope of the multi-screen approach – and indeed, of TRIZ – is identifying solutions to technical problems. Therefore, a key research issue, when using such methods, is whether designers might be able to use such a method to anticipate not technological evolutions, but evolutions in use.

III. OVERVIEW OF OUR METHODOLOGICAL PROPOSAL

In examining the commonalities between TRIZ and CPS, two things become apparent. First, both paradigms aim to improve creative performance in groups by placing designers in situations with a more favorable cognitive and social climate, in order to allow them to access a wider range of knowledge. Second, although TRIZ and CPS tools are most commonly used to solve technical issues or to propose new design concepts, it is likely that methods and tools to enhance creativity might help designers better anticipate future use in the early stages of the design process. Table 2 summarizes our argument in favor of the use of creativity tools to assist prospective use analysis.

TABLEAU 2. *Arguments en faveur de l'utilisation des outils TRIZ et CPS pour l'anticipation d'usages futurs*

Table 2. Arguments in favor of using TRIZ and CPS tools to anticipate future use

Issues in anticipating future use	**Expected benefits of TRIZ (multi-screen approach)**	**Expected benefits of CPS (brainwriting)**
Limited knowledge base	– Collaborative work – Extending the search space through analogical reasoning	– Free expression of multiple points of view – Extending the search space through associative reasoning
Cognitive aspects	– Solution-finding is based on combining several levels of analysis and several known solutions (alternative products)	– Rapid, freewheeling generation of ideas – Intra- and interpersonal stimulation in idea generation
Social aspects	– Criticism is barred	– Criticism is barred

This review suggests that creativity methods are a worthy addition to the toolset of Prospective Ergonomics, a point also made recently by Zeng, Proctor, and Salvendy (2010). However, when examining in more detail the approaches of CPS and TRIZ, one should also point out that these two approaches focus on producing ideas/solutions to solve specific problems. This is very different from defining scenarios of future use, which are defined as stories about people aiming to help decision-making in design. Stories are more than just ideas: they serve as support to the generation of new ideas. However, de Sá and Carriço (2008) point out that prospective scenarios of use can be built by combining several variables – places, users, etc. – in unexpected and interesting configurations. This concurs with a basic principle of creative production: a typical process of creative design implies successive cycles of divergence and convergence (Cropley, 2006). Based on this, we have proposed a three-stage process model for prospective use analysis. These stages are indicated in Figure 2.

The first two stages of this model aim to generate speculative scenarios of use. First, based on a design brief, designers generate ideas related to potential future use (divergent thinking, represented by triangles pointing left). Second, ideas are selected (convergent thinking, represented by triangles pointing right) and immediately expounded in the form of scenarios. These serve as grounds to select a product concept for further development and, ultimately, market launch.

In this paper, we explore two possible ways to assist the generation of scenarios of use in Prospective Ergonomics:

Creative Problem Solving (Figure 2, top). Brainwriting, a method commonly used in the Creative Problem-Solving process to achieve ideational divergence (point 1, see section II.3.1), will be followed by morphological analysis (Voros, 2009) to assist convergence (point 2). In morphological analysis, ideas are selected and serve as input for a matrix. Each cell of the matrix is then explored to generate one or more creative scenarios of future use by combining ideas two by two;

The multi-screen approach (Altshuller, 1996 - Figure 2, bottom), borrowed from the Russian Theory of Inventive Problem-Solving (see section II.3.2). We believe that this tool can be used by designers to extrapolate scenarios of future use based on their knowledge of trends in the use of past and present products.

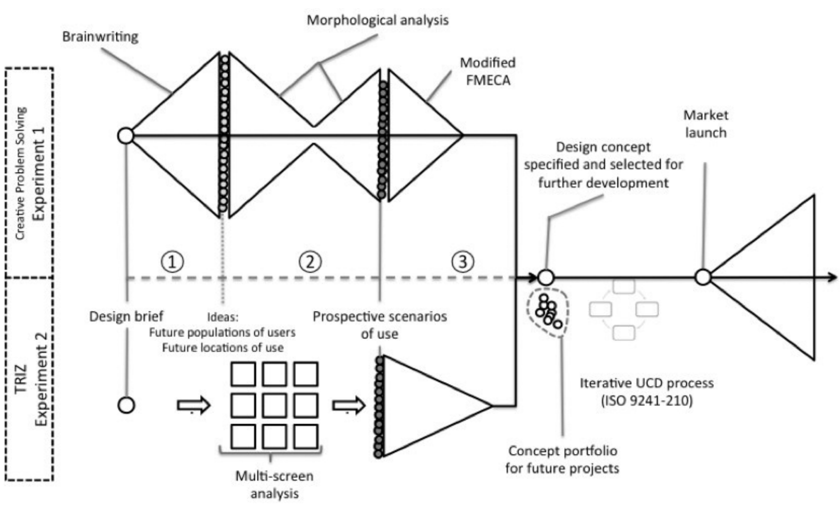

Figure 2 – Vue d'ensemble de notre proposition méthodologique pour assister l'analyse prospective des usages.

Figure 2 – Overall view of our methodological proposal to assist prospective use analysis. FMECA: Failure Modes, Erors and Criticality Analysis; UCD: User-Centered Design.

In stage 3 of our process, scenarios must be selected using a convergence method to help prioritize them within a project portfolio. Returning to the framework of scenario-based design, it appears that scenarios are judged based on positive or negative claims (Rosson & Carroll, 2002). These claims aim to answer a simple question: does the scenario describe desirable, or conversely, undesirable situations? Failure Modes, Errors and Criticality Analysis (FMECA) is a typical method used to help structure reasoning to anticipate *a priori* failures of complex technical systems.

Figure 2 illustrates the whole of our methodological proposal. Its originality lies in the fact that (*a*) it introduces and illustrates the use of creativity methods to help anticipate future use in the design of new products, and (*b*) it is fully compatible with existing approaches of UCD and acknowledges that design continues in use, as the product's identity continues to evolve through its interactions with users (Folcher, 2003). In the next sections, we describe two experiments aiming to assess the benefits and drawbacks of integrating creativity tools from two different paradigms in this process model, to produce speculative scenarios of future use. Section 4 focuses on Creative Problem Solving, represented by the tools of brainwriting and morphological analysis, while section 5 focuses on the TRIZ paradigm, represented by the multi-screen diagram.

IV. EXPERIMENT 1: EFFECT OF CPS METHODS ON IDEATIONAL ORIGINALITY

IV. 1. Participants

Participants were 32 people (11 M, 21 F) aged 20 to 71 years (M=36.1, SD=16.1). They were recruited based on their field of professional expertise: one quarter of subjects were design engineers, one quarter product designers, one quarter Human Factors specialists and one quarter, termed "naïve" subjects, had no prior experience in design. Participants were divided into eight teams of four participants, each team comprising one subject from each profile (1 engineer, 1 product designer, and so on).

IV. 2. Materials

Eight simulated design meetings took place in a meeting room at our laboratory. Each team was provided with a design brief, describing (*a*) the intended technical attributes and operation of the product they were to design, and (*b*) design roughs and/or illustrations of the product concept. Teams worked on either of two projects:

– The design of an interactive tabletop interface with multi-user, multi-touch technology to assist collaborative activities. Because this project is essentially driven by the need for technological development, the design of such a product starts from a very open design brief. We chose this project because anticipating scenarios of use at this point in the design process may help designers identify worthwhile applications for future development – in other words, to provoke change (see section II.2);

– The design of an inflatable necklace to prevent drowning in infants. Although the product concept is better specified than in the example above, it is unclear whether it will be able to provide better protection than existing devices (e.g. barriers, inflatable armbands, etc.). We chose this project to assess the use of our methodology in the slightly later stage of concept validation and refinement. The goal here, again in the terms introduced in section II.2, is to anticipate change.

Participants were given post-it pads for the brainwriting task and sheets of paper to record their ideas for future scenarios of use. Different color pens were used for each participant profile to record the authorship of generated ideas. The sessions were videotaped with prior collection of participant approval, using a camera focused on the work area.

IV. 3. Procedure

Participants were asked to "anticipate as many uses as possible" for the product they were working on, working as a team and using the sheets of paper to record their ideas. These instructions were deemed to reflect those that might be given in a Prospective Ergonomics workshop. Two conditions were used:

– In the native condition, teams were given no other instructions and had 30 minutes to achieve the task;
– In the creative condition, they were read aloud the rules of brainwriting, as devised by Paulus and Yang (2000). This procedure uses Osborn's (1957) four brainstorming rules (see section II.3.1), but participants are instructed to silently share written ideas amongst themselves. Contrary to Paulus and Yang's procedure, ideas were not written on slips of paper but on post-it notes to facilitate the later stages of the experiment. In the brainwriting task, participants were asked to answer the following questions: (1) "Who might the future users of this product be?" and (2) "Where might this product be used?" The time allotted for each question was five minutes. Participants were then asked to work as a team to select the five answers they thought most interesting for each of the two questions, and to use the post-its to construct a 5-by-5 matrix for morphological analysis, crossing users and places of use. They were then given 20 minutes to fill in the matrix, using the blank idea sheets to record their ideas in terms of prospective scenarios of future use.

Teams worked successively under the two conditions, native and creative. A counterbalanced design was used to control the effects of task order and project (interactive tabletop interface and inflatable anti-drowning necklace).

IV. 4. Data collection and analysis

All written productions – post-its describing ideas related to future users and use locations, and idea sheets describing scenarios – were collected, and participants' oral utterances were transcribed verbatim using the *Transcriber* software program (Barras, Geoffrois, Wu, & Liberman, 2001). Redundancies between oral and written creative production were filtered out to better determine the authorship of the various ideas produced. Indeed, in many sessions, teams appointed a "scribe" to write down the scenario ideas that emerged in the conversation. In this case, authorship was given to the person who uttered the idea orally, not to the scribe.

Although Osborn's original work on CPS greatly emphasized the importance of ideational fluency, creativity can be assessed following various criteria. Torrance (1995) summarizes four criteria commonly used to assess creative production: "*The number of relevant responses produced by a subject yields one measure of ideational fluency. The number of shifts in thinking or number of different categories (…) gives one measure of flexibility. The statistical infrequency of these (…) or the extent to which the response represents a mental leap or departure from the obvious and commonplace gives one measure of originality. The detail and specificity incorporated into questions and hypotheses provide one measure of ability to elaborate*" (our emphasis). Our goal here was to assess the creative performance of designers involved in simulated design meetings, aiming to specify possible future uses of a product based on its design brief.

In the methodology we chose to describe designer activity in these meetings, we sought to reflect the diversity of these criteria for creative performance. In this study, we selected two criteria of particular interest to innovative design: ideational fluency and originality. To assess fluency, we followed the traditional approach of "counting ideas" (Nelson et al., 2012). However, in the present paper, we have chosen to focus more specifically on the criterion of ideational originality. Typically, this relies on using normative data about the responses most commonly produced in a creative task. Since such normative data were unavailable in our case, we assessed originality based on the following two criteria:

- Whether the idea was a recurring one within the eight teams of participants;
- Whether the topic was referenced equally often in the creative vs. native conditions.

To achieve this, we determined, for each reference in each of the topics mentioned above (users, use environment, and user activities), the number of times it was uttered across all teams. From there, we calculated two variables:

- The reference rate (RR) of each topic: this was either classified as weak (the topic is mentioned only once between all teams), medium (2-4 references) or high (5 references or more);
- The "creative-native delta" (CND): this was obtained by subtracting, for each topic, the number of references across teams made in the native condition, to those made in the creative condition. References were then classified, as above, in three groups. Positive CNDs indicated

topics that appeared more often in the creative than in the native condition. Null CNDs indicated topics that were mentioned equally often in either condition. Negative CNDs indicated the topic was mentioned less often in the creative than in the native condition.

IV. 5. Results

In prior work on this experimental setup (Nelson et al., 2012), ANOVA on the fluency variables showed that the use of the CPS methods in Figure 2 yielded no significant effect on the number of *scenarios* generated within the time allotted for task completion, nor on the number of ideas generated regarding *future users* and *user activities*. CPS tools only exerted a positive effect on the number of ideas generated in relation to *future locations of use*, but not on the other variables.

The focus of this paper is on the originality variables. A chi-square test showed a significant effect of the condition on the reference rate. The creative condition was found to be highly attracted to high RRs, regarding references to both future users ($Chi^2(2)=24.93$, $p<0.001$) and locations of use ($Chi^2(2)=11.98$, $p=0.003$). The native condition, conversely, was more attracted to weak RRs. The RR is an index for topic homogeneity between teams of participants. This suggests that CPS methods allow designers to structure their discussions of future use around a limited number of central topics. In the native condition, few such topics emerged, and they remained very vague, *e.g.* [using the interactive tabletop interface] "at work" or "in meetings", for "everybody", for "professionals"; [using the necklace] "outside", "in a swimming pool", "by the sea". In the creative condition, these topics were abandoned in favor of more numerous and more specific high-RR topics, *e.g.* [using the table] in a train, in the classroom, etc.; [using the necklace] inside the house, in retirement homes, for babies, for disabled people, for the elderly, etc. CPS methods thus allow new topics for UCD to emerge and to gain legitimacy in the design team.

A chi-square test also found the project to have an effect on the RR for location topics ($Chi^2(2)=11.89$, $p=0.003$). The table project was found to be more attracted to medium and high RRs, and the necklace project more attracted to weaker RRs, suggesting a less structured exploration in the latter case.

CND results allowed us to assess the effects of the CPS methods on ideational expansion. A t test indicated that the CND was significantly greater than zero for references to both user populations ($t(186)=6,60$, $p<0,001$) and locations of future use ($t(212)=5,49$, $p<0,001$). This suggests that CPS methods allowed a statistically significant expansion of these two sets of ideas. The project variable did not have any significant effect on CND for ideas related to the identity of future users ($t(185)=1,14$, NS). However, a significant effect was observed for future locations of use ($t(211)=2,59$, $p=0,01$) and user activities ($t(212)=2,08$, $p=0,039$). For these two categories of items, the CND was found to be significantly greater in groups working on the table project, than in those working on the necklace project.

V. EXPERIMENT 2: EFFECTS OF TRIZ TOOLS ON ABILITY TO GENERATE PROSPECTIVE SCENARIOS OF USE

V. 1. Participants

Eight professionals (6 M, 2 F) from various fields of design (design engineers, product designers, etc.), were recruited to take part in a TRIZ workshop aiming to test a new methodology derived from multi-screen analysis. Participants were aged 24 to 50 years (M=32.6, SD=8.8) and had on average 9.9 years of experience in their field (SD=7.7). The team included one TRIZ expert who took on the role of a facilitator in this workshop.

V. 2. Materials and procedure

Following a primer on TRIZ and, more specifically, on multi-screen analysis (lasting approximately 45 min.), the group was instructed to attempt to adapt this method to anticipate future uses of the digital tabletop interface mentioned in experiment 1, using the materials presented in section IV. 2. The instruction given was as follows: “Your goal is to anticipate possible future uses for this digital table”. Once again, this instruction was chosen because it was thought that it could be used in a future Prospective Ergonomics workshop. This work session lasted approximately two hours. As before, the session was videotaped with the approval of all participants.

V. 3. Data collection and analysis

In this second experiment, our goal was not necessarily to assess the effects of a new tool on participant performance in a creative production task. The primary focus of TRIZ is solving technical innovation problems; therefore, a preliminary step is required before adapting TRIZ tools to user-related issues. One should first assess how a design team will be able to use an existing TRIZ tool for the purpose of formulating hypotheses regarding future use. This requires focusing data analysis not on idea production, but on the contents and orientations of the design team’s discourse. Using the feed from the camera, we transcribed the verbal utterances produced by all workshop participants, as they constructed the multi-screen diagram.

In choosing a method for the analysis of this verbal production, we drew inspiration from work concerning the dynamics of argumentation in design meetings (Détienne, Martin, & Lavigne, 2005). Our goal here was not to model argumentative processes, but to examine to what extent the group was able to adapt the use of the multi-screen diagram to anticipate possible future uses of the digital tabletop interface. To this end, the contents of the entire conversation – comprising 10,240 words and 485 speech turns – were analyzed.

We isolated within participants’ discourse the utterances related to three different topics, namely *(a)* technical artifacts or products; *(b)* elements of scenarios of use, in particular – as in experiment 1 above – the characteristics of future users and locations of use; and *(c)* prospective scenarios of use. We then defined two variables to specify what part of the nine-screen diagram each utterance referred to. One variable referred to location in time (past, present or future). Another referred to the level of abstraction in systems thinking (subsystem, system or super-system). Table 2 indicates the rules we used to sort the utterances following these two variables. When none of these rules applied, the reference was given a fourth value, noted "undetermined".

To account for the topics mentioned in the meeting, three dependent variables (DVs) were defined: the number of mentions made to a technical artifact, to a specific subcomponent of the use scenario (*e.g.* users, locations, etc.), and finally, to scenarios as a whole. We hypothesized that, by using the multi-screen diagram, participants would be able to produce a discourse focusing on future use. In statistical terms, we expected to uncover a significant attraction of participants' verbal production to the "future super-system" cell of the nine-screen diagram.

V. 4. Results

Chi-square tests were carried out using SPSS on the data derived from the meeting corpus, using the rules in Table 2. The test yielded significant results, indicating that the designers had successfully focused their discourse on a future timeframe. But we observed this only for the utterances related to technical artifacts ($Chi^2(6)=26{,}2$, $p<.0001$). For the other DVs, concerning the scenario subcomponents and the scenarios themselves, the results were not significant.

Tableau 2 : *Schème de codage des énoncés verbaux*

Table 2. Coding scheme for the verbal utterances

IV#1: Timeframe		
Value	**Criterion**	**Example (from corpus)**
Past	The author of the utterance mentions a situation clearly referring to artifacts preceding the interactive table, AND/OR the sentence is in the past tense.	*"No, I mean, if I take past subsystems, taking the table for example, it's just the board and the legs. There really isn't much point."*
Present	The author mentions situations that clearly refer to current uses of tabletop interfaces or similar contemporary products, AND/OR the sentence is conjugated in the present tense.	*"The Information System, that is the IS, that's my calculator, my piloting system. Do you think that'll do for now? And apart from that, I have chairs, right? (…) OK, what does all that stuff integrate into today?"*

Future	The author refers to situations clearly describing the future use of the tabletop interface to be designed, AND/OR the sentence is conjugated in the future tense.	*"OK, let's say fifteen years from now, there will have been technological evolutions, that is the uses will have evolved and the technological potential will have evolved."*
IV#2: Abstraction level in TRIZ		
Value	**Criterion**	**Example (from corpus)**
Subsystem	The author refers to the technical components in the table or any other system.	*"No, what I mean is perhaps we're not looking for evolutions in the product as a whole, maybe just evolutions in the software, like new functions".*
System	The author refers to the table or any other technical system.	*"Should the system not be something like a digital creativity tool?"*
Supersystem	The author refers to the table interacting with other objects and/or with users, in a situation of use.	*"Doesn't the fact of saying "I'll implement tools for collaboration"… doesn't it force people to start working together, or at least to start meeting with each other?"*

VI. DISCUSSION AND CONCLUSIONS

Our previous work had suggested that CPS tools exerted only minor effects on ideational fluency related to imagining scenarios of future use (Nelson et al., 2012). In the present paper, we were able to explore the effects of these tools from the point of view of originality. Teams using brainwriting and the discovery matrix were able to converge more efficiently towards common topics, but also to explore these topics in greater depth than groups who did not, leading to more original ideas. These findings can be explained using the "*path-of-least-resistance*" hypothesis of group idea generation (Ward, 1994). Designers are more likely to start by exploring situations that are the most readily accessible to memory – e.g. personal experiences or representations of everyday use – before moving on to more original ideas, if time allows it. Therefore, in the situation studied here, CPS methods seem to boost creative performance more from a qualitative than a quantitative point of view.

In this paper, we were also able to examine the possibility of adapting a tool from the TRIZ method to assist the anticipation of future use. Although the general approach of the nine-screen diagram – i.e. extrapolating future scenarios of use based on the examination of past trends – is interesting, our results suggested that participants were unable to "repossess" this tool to generate prospective scenarios of future use. Further work will be needed before TRIZ techniques can be adapted to, and their potential fully harnessed by prospective ergonomics.

These early results raise many questions, which should be viewed not just as challenges, but also as opportunities for the development of prospective ergonomics. First, in this work, we have addressed how to help designers envision future uses for innovative products (Woods, Tittle, Feil, & Roesler, 2004). The next logical step is to ask whether these anticipations can provide an accurate view of actual future uses. This question could be answered through longitudinal studies of product use and user experience.

A second point relates to the ecological validity of the experimental tasks in both studies. Because prospective ergonomics is an emergent practice in our field, this question might only be answered (a) by encouraging the transfer of research findings to ergonomics practice, and (b) by performing analyses of ergonomists' activity in prospective interventions, as some authors have done in the past in other areas of ergonomics practice (Petit, Querelle, & Daniellou, 2007).

Since the publication of Robert and Brangier's paper (2009), prospective ergonomics has taken major strides towards being recognized as a promising topic for ergonomics research and practice. As we have argued in this paper, validating methodologies for interventions in prospective ergonomics seems to be a crucial milestone towards this goal. The two paradigms of creativity we have examined – CPS and TRIZ – offer a wide variety of tools that could be used to anticipate the potential of innovative technologies for human use, provided these tools are subjected to scientific validation. It is our belief that research can and should provide practitioners with the means to fulfill the ambitions of prospective ergonomics. In so doing, research will necessarily question the role of ergonomists in innovative design – viewing them not just as analysts of the performance and well-being of people using existing products and work systems, but as agents of foresight and creativity in the design process.

REFERENCES

Altshuller, G.S. (1996). … *And suddenly the inventor appeared*. Worcester, UK: Technical Innovation Center.

Barras, C., Geoffrois, E., Wu, Z., & Liberman, M. (2001). Transcriber: Development and use of a tool for assisting speech corpora production. *Speech Communication, 33*(1-2), 5-22.

Bonnardel, N. (2009). Activités de conception et créativité : de l'analyse des facteurs cognitifs à l'assistance aux activités de conception créatives. *Le Travail Humain, 72*(1), 5-22.

Brangier, E., & Bastien, J.M.C. (2006). L'analyse de l'activité est-elle suffisante et/ou pertinente pour innover dans le domaine des nouvelles technologies? In G. Vallérv & R. Amalberti (Eds.), *L'analyse du travail en perspectives: influences et évolutions* (pp. 143-156). Toulouse: Octarès.

Cavallucci, D. (1999). *Contribution à la conception de nouveaux systèmes mécaniques par intégration méthodologique*. Doctoral dissertation, Université Louis Pasteur, Strasbourg.

Cropley, A. (2006). In praise of convergent thinking. *Creativity Research Journal, 18*(3), 391-404.

Daniellou, F. (1992). *Le statut de la pratique et des connaissances dans l'intervention ergonomique de conception* (2ème ed.). Bordeaux: Editions du LESC de l'Université Victor Segalen Bordeaux 2.

Daniellou, F. (2007). Simulating future activity is not only a way of improving workstation design. *@ctivités, 4*(2), 84-90.

de Sá, M., & Carriço, L. (2008). *Defining scenarios for mobile design and evaluation.* Paper presented at the CHI2008 conference, April 5-10, Florence, Italy.
Détienne, F., Martin, G., & Lavigne, E. (2005). Viewpoints in co-design : a field study in concurrent engineering. *Design Studies, 26*(3), 215-241.
Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups : towards the solution of a riddle. *Journal of Personality and Social Psychology, 53*(3), 497-509.
Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., van der Doelen, B. (2012). A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics, 55*(4), 377-395.
Dul, J., & Neumann, W. P. (2009). Ergonomics contributions to company strategies. *Applied Ergonomics, 40*(4), 745-752.
Durand, J., Weite, P. A., Gazo, C., & Lutz, P. (2007,). *Determination and evaluation of the possible links and sequences between TRIZ and other design methods.* Paper presented at the International Conference on Engineering Design, ICED'07, August 28-31, Paris.
Folcher, V. (2003). Appropriating artifacts as instruments : when design-for-use meets design-in-use. *Interacting with Computers, 15*(5), 647-663.
Godet, M. (2007). *Manuel de prospective stratégique* (Vol. 2). Paris: Dunod.
Hatchuel, A., Le Masson, P., & Weil, B. (2002). From knowledge management to design-oriented organizations. *International Social Science Journal, 54*(171), 25-37.
Leonard-Barton, D. (1992). Core capabilities and core rigidities: a paradox in managing new product development. *Strategic Management Journal, 13*, 111-125.
Liem, A., & Brangier, E. (2012). Innovation and design approaches within prospective ergonomics. *Work, 41*, 5243-5250.
Maguire, M. (2001). Methods to support human-centered design. *International Journal of Human-Computer Studies, 55*, 587-634.
Nelson, J. (2011). *Contribution à l'analyse prospective des usages dans les projets d'innovation.* Doctoral dissertation, Arts et Métiers ParisTech, Paris.
Nelson, J., Buisine, S., & Aoussat, A. (2012). A methodological proposal to assist prospective ergonomics in projects of innovative design. *Le Travail Humain, 75*(3), 279-305.
Nelson, J., Buisine, S., & Aoussat, A. (2013). Fostering creativity in the definition of future product use : a framework to assist user centered design and innovation. *Applied Ergonomics, 44*(6), 948-956.
Osborn, A.F. (1957). *Applied imagination*. New York, NY: Scribner.
Parnes, S.J., & Meadow, A. (1959). Effects of «brainstorming» instructions on creative problem solving by trained and untrained subjects. *Journal of Educational Psychology, 50*(4), 171-176.
Paulus, P.B. (2000). Groups, teams and creativity: the creative potential of idea-generating groups. *Applied Psychology, 49*(2), 237-262.
Paulus, P.B., & Yang, H. C. (2000). Idea generation in groups: a basis for creativity in organizations. *Organizational behavior and human decision processes, 82*(1), 76-87.
Petit, J., Querelle, L., & Daniellou, F. (2007). Quelles données pour la recherche sur la pratique de l'ergonomie ? *Le Travail Humain, 70*(4), 391-411.
Robert, J.-M., & Brangier, E. (2009). *What is prospective ergonomics? A reflection and a position on the future of ergonomics.* In B.-T. Karsh (Ed.), *Ergonomics and Health Aspects* (pp. 162–169). LNCS 5624, Springer Verlag.
Robert, J.-M., & Brangier, E. (2012). Prospective ergonomics: origin, goal, and prospects. *Work, 41*, 5235-5242.
Rosson, M.B., & Carroll, J.M. (2002). *Usability engineering: scenario-based development of human-computer interaction*. San Diego, CA: Academic Press.
Savransky, S.D. (2000). *Engineering of creativity : introduction to TRIZ methodology of Inventive Problem Solving*. Boca Raton, FL: CRC Press.
Torrance, E.P. (1995). Insights about creativity: questioned, rejected, ridiculed, ignored. *Educational Psychology Review, 7*(3), 313-322.

van Belleghem, L. (2012). Simulation organisationnelle : innovation ergonomique pour innovation sociale. In M.F. Dessaigne, V. Pueyo & P. Béguin (Eds.), *Actes du 47ème congrès de la Société d'Ergonomie de Langue Française*. Lyon: Editions du GERRA.

Veyrat, N. (2008). *Les usages dans la lunette : co-concevoir des produits et des usages innovants.* Doctoral dissertation, UPMF, Grenoble.

Voros, J. (2009). Morphological prospection : profiling the shapes of things to come. *Foresight, 11*(6), 4-20.

Ward, T.B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology, 27*(1), 1-40.

Woods, D.D., Tittle, J., Feil, A., & Roesler, A. (2004). Envisioning human-robot coordination in future operations. *IEEE Transactions on Systems, Man, and Cybernetics, 34*(2), 210-218.

Zeng, L., Proctor, R.W., & Salvendy, G. (2010). Creativity in Ergonomic Design: A Supplemental Value-Adding Source for Product and Service Development. *Human Factors, 52*(4), 503-525.

SUMMARY

Prospective ergonomics is concerned with the anticipation of future needs and activities to assist the early stages of user-centered innovation design projects. Few studies have proposed methodologies to assist prospective ergonomics, although this is a key to better integrating user-centered design in innovation projects. Indeed, classical methods of use analysis are of limited relevance when designers must work with ill-defined product concepts, since it may be difficult to describe future uses for these products. In this paper, we argue that some creativity methods, often used to solve technical design problems, can be used to construct speculative scenarios describing the future use of a product. We carried out simulations of design meetings, focusing on anticipating the future uses of various products. In two studies, we assessed the effects of methods borrowed from two creativity paradigms on the ability of a multidisciplinary design team to formulate prospective scenarios of future use.

The first study aimed to assess the contribution of methods borrowed from the Creative Problem Solving (CPS) paradigm – brainwriting and the discovery matrix – to the production of prospective scenarios of future use. Results show that these methods allow a more structured exploration of the space of creative ideas, leading to more original ideas.

In the second study, we examined the ability of a design team to use multi-screen analysis – a method borrowed from the Theory of Inventive Problem-Solving (TRIZ) – to construct a discourse on the future uses of an innovative product. Results suggest that the team was able to anticipate future evolutions of the technical artifact considered – which is the goal of the method in its classical form – but not to reappropriate this technique to imagine scenarios illustrating future uses of a product. We describe the consequences of these results for developing new methodologies for interventions in prospective ergonomics.

Keywords*: Prospective ergonomics, innovation, conceptual design, scenario-based design, creativity.*

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