Inventing Requirements with Creativity Support Tools

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Abstract. [**Context and motivation**] Creativity is indispensable for software systems to deliver progress and competitive advantage for stakeholders. Yet it is rarely supported in requirements processes. [**Question/problem**] This paper investigated integration of two software tools, one for generating requirements with scenarios, the other for supporting people to think creatively while finding and collecting information. The effectiveness of the integration was investigated. [**Principal ideas/results**] The technical integration is described, and an evaluation is reported. [**Contribution**] Results reveal some effect on the novelty of the requirements generated, and have implications for the design of tools to support creative requirements processes.

Keywords: Requiremensts discovery, creativity, creativity support tools.

1 Creating Requirements

Requirements engineering is a creative process in which stakeholders and analysts work together to create ideas for new software systems, which are expressed as requirements. Creativity is indispensable if software systems are to deliver progress and competitive advantage, yet it is rarely supported in requirements tools. In this paper we describe the integration of a requirements tool and a creativity support tool, then report how analysts used the integrated tools to specify requirements of a new secure access system.

Most current requirements processes and tools support problem analysis and system specification [17]. An assumption is that stakeholders already know their requirements. However, this is not always true, because stakeholders are not aware of what new technologies can do. As technologies evolve, stakeholders need to create novel requirements by connecting knowledge of the problem with information about relevant technologies. This means engaging in a form of creativity known as information discovery, in which processes of finding, collecting, and arranging information stimulate the emergence of new ideas [8]. In software development new ideas are often expressed as requirements.

Previously we applied theories and models of creativity in workshops to support stakeholders to discover requirements for complex systems in domains including air

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traffic management and food traceability. However, although successful in terms of the number and the impact of requirements generated [11, 12], the workshops were resource-intensive. Each could involve up to 20 stakeholders and analysts for 2 days, and our support for creative thinking was not available during other requirements processes.

To support people's creative thinking effectively throughout a requirements process, we sought to deliver new tools. Whilst creativity support tools are available, none have been explicitly built to support requirements processes. Therefore we integrated ART-SCENE, a tool designed to discover more complete requirements with scenarios, with combinFormation, a tool that supports people in creating new ideas while finding and collecting information. The remainder of this paper is in 6 sections. Sections 2 and 3 describe ART-SCENE and combinFormation, and their integration, then section 4 describes how an analyst might use the integrated tools. Section 5 reports results for a preliminary evaluation of the integrated tools. The paper ends with a review of related work and future research plans.

2 Enhancing Scenario Walkthroughs

Scenarios are an effective requirements technique, and ART-SCENE is an internet-based environment that uses scenarios to discover more complete requirements. Stakeholders have applied ART-SCENE successfully to discover requirements on software systems in domains ranging from air traffic control to work-based learning [14].

ART-SCENE delivers two important capabilities to stakeholders. The first is automatic scenario generation. ART-SCENE automatically generates one or more scenarios with different normal course event orderings and alternative courses from a use case specification. The second capability is guided walkthroughs of these generated scenarios. The big idea behind walkthroughs is very simple – that people are better at recognition than recall [1]. ART-SCENE scenario walkthroughs offer stakeholders recognition cues in the form of generated alternative courses. If the alternative course is relevant to the system being specified but not yet handled in the specification, then a potential omission has been identified. ART-SCENE guides the stakeholders to specify more complete requirements.

Automatically generated scenarios in ART-SCENE are delivered to stakeholders using a web client shown in Figure 1. The left-side menu provides functions for viewing the scenario and requirements generated for it. Top-line buttons offer walkthrough functions (e.g. next or previous event) and functions to add, edit or delete events, comments and requirements. The left-hand main section contains the sequence of events of a scenario that describe the behaviour of a system, in this case security access to a building. Event 1 describes the start of an action: *user walks up to the security gate*. The right-hand main section describes generated alternative courses for each normal course event, presented in the form of 'what-if' questions. The top-listed alternative course is *what if the user is physically unable to undertake this action*? Alternative courses are generated for different normal course events. If no requirements are specified to handle an event that is recognised as relevant, then omissions have been discovered and new requirements can be written, thus increasing requirements completeness.

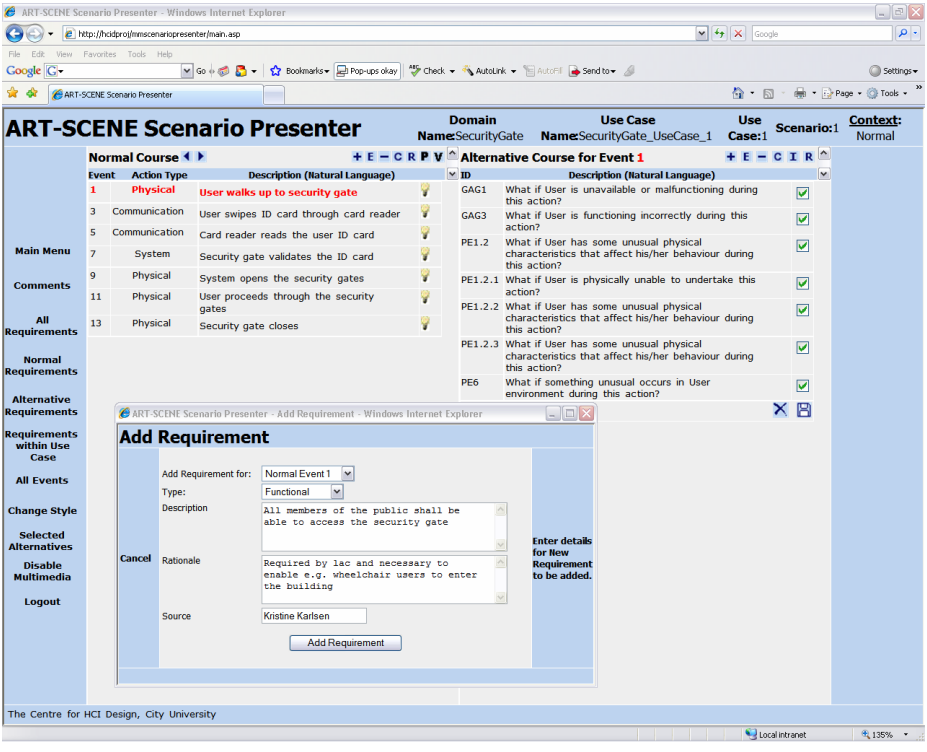


Fig. 1. A snapshot of ART-SCENE, showing one scenario for a security access system, describing the event *user walks up to security gate* (left side), automatically generated alternative courses for the highlighted normal course event (right side), and one generated requirement in a VOLERE form

Returning to the example, if *the user walks up to the security gate*, and *the user is physically unable to undertake this action*, stakeholders might generate new requirements to handle this event, such as *all members of the public shall be able to access the security gate*.

One benefit of using scenarios in ART-SCENE has been improved communication between stakeholders, especially in distributed settings where communication is asynchronous. Scenarios provide a shared context and lingua franca for people in different places to communicate about requirements. To facilitate this communication, ART-SCENE supports a server-side scenarios and requirements database that can be accessed by stakeholders in distributed settings.

3 Extending ART-SCENE with Creativity Support

ART-SCENE did not explicitly support stakeholders in thinking creatively about requirements. Therefore we worked to extend scenario walkthroughs with creativity stimuli, as stakeholders work to develop requirements. Sternberg's defines creativity

as "*the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)*" [22]. The goal was for digital information stimuli to support stakeholders in creating requirements that are novel and useful.

We integrated ART-SCENE and combinFormation, a creativity support tool for searching, browsing, collecting, mixing, organizing and thinking creatively about digital information [7, 8, 9, 10]. combinFormation is regularly used by 1000 undergraduate design students each year to collect existing work as they create new designs.

3.1 combinFormation

combinFormation is a freely available [7] mixed-initiative [6] system that integrates searching, browsing, and exploring information [9, 10]. It has been developed as an extensible platform with a modular object-oriented architecture. Software agents procedurally extract clippings from documents, which function as surrogates, and assemble them in a visual c*omposition space* storyboard, shown in Figure 2. A *surrogate* is an enhanced bookmark, which represents an important idea in a document, and enables navigation back to the document. Visual surrogates are formed by extracting images, and augmenting them with metadata. *Composition* functions a means for representing a collection of surrogates as a connected whole, instead of as separate elements, as in a list. The visual composition is procedurally generated over time, like a dynamic video. Related surrogates are automatically clustered. Procedural generation iteratively places visual surrogates into the composition space, where the participant can see and manipulate relationships among them. By making ideas and relationships visible, the composition space can stimulate cognitive restructuring, and creative ideation. Design tools enable authoring task-oriented collections as navigable compositions. Visual characteristics, such as colors, sizes, fonts, sizes, layout, and compositing can be adjusted. Spatial relationships and visual characteristics are used to connect ideas. Compositing blends surrogates visually, by using alpha masks.

The user engages in processes of searching, browsing, collecting, and authoring media in the composition space, which serves as a visible medium for communication between human and agent, as well as for thinking about and sharing information resources. Users can directly experience the juxtaposed surrogate clippings, and they can also navigate back to source documents for more in-depth information. Compositions can be saved reopened, shared, and published.

A combinFormation session is initiated by the user through the specification of seeds. Each seed is a search query, website, or news feed. The top left of Figure 2 shows a process of seeding combinFormation, in this case to develop a composition relevant to requirements generation for a secure access system, and the resulting composition space. Queries included terms such as *physical security* and *security gate*. The outer area is the mixed-initiative Hot Space, which is shared by combinFormation's visual composition agent and the user. Surrogates stream directly into this space. The inner area is the Cool Space, available only to the user for constructing a compositional storyboard of the surrogates most relevant to the task at hand, using drag and drop. As the user fills the Cool Space storyboard with relevant content, s/he can enlarge it to allocate more of the visual area for her own use, leaving less for the agent.

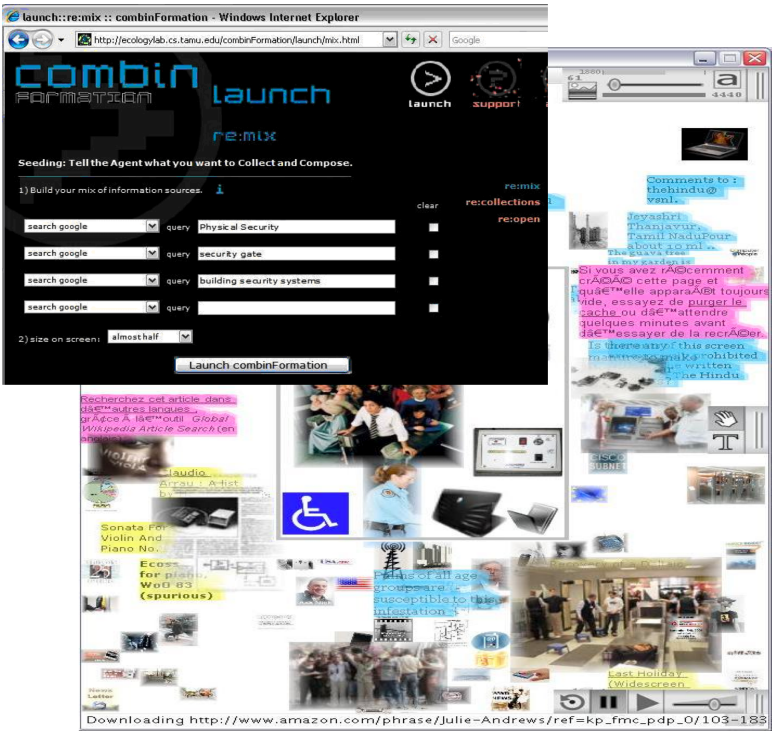


Fig. 2. Launching combinFormation by issuing multiple search queries as seeds for mixing (e.g. "Physical Security" and "security gate") in the top left-hand corner, and the composition space filled with retrieved surrogates. The user organizes relevant surrogates by dragging them into the center Cool Space, and adjusting their visual characteristics and relationships.

As part of integrating ART-SCENE and combinFormation, we developed a new ART-SCENE component called the Creative Requirements Innovation Space (CRIS). CRIS provides analysts with a flexible storyboarding space in which to explore, combine and transform ideas prior to generating requirements.

3.2 CRIS: The Creative Requirements Innovation Space

We designed CRIS to emulate how people in our creativity workshops generate new associations between concepts using creativity techniques. In workshops, stakeholders browse and associate ideas, place them on pin boards, then elaborate these ideas in storyboards that combine graphics and text to describe new system behaviour [12]. Using CRIS the analyst explores associations between image and text elements presented by combinFormation, then pulls these elements into CRIS to connect them with requirements.

So how did the tool integration work? We designed ART-SCENE to extract key terms dynamically from scenario event descriptions, and pass them to combinFormation to seed searches and download web pages to create collections of surrogates and links displayed in its composition space. An analyst then used combinFormation to

manipulate surrogates in the composition space and the visual representation of the collection. To document requirements, the analyst opened another storyboard in CRIS, dragged selected surrogates from the composition space to construct a storyboard for each scenario normal course event, then documented one or more structured requirements through VOLERE forms. The storyboard and requirements were stored in the ART-SCENE database, which met one important need – that storyboards and requirements can be shared between stakeholders working in distributed settings with the same ART-SCENE scenario.

To facilitate rapid storyboarding, the analyst could directly drag elements from the Composition Space and/or any existing web-site into the CRIS storyboard, then resize, label and delete elements, combine elements together, save the storyboard, reopen it later, and share it with other stakeholders. To minimize resource consumption and quicken response times, most CRIS functions were client-side, and client-server communication only happened when the analyst stored a storyboard in the database.

The next section demonstrates how this architecture supports an analyst to generate and use CRIS storyboards during an ART-SCENE scenario walkthrough.

4 ART-SCENE and combinFormation to Invent Requirements

The security access scenario in Figure 1 has 7 discrete normal course events, from *user walking up to a security gate* to *the security gate closes*, and alternative courses generated to ensure requirements completeness. For any selected use case event, the analyst can request creativity support by clicking the corresponding light bulb icon, then edit and extend the terms in the event description – for example *user, walk and security gate*. ART-SCENE seeds combinFormation with the extracted event terms.

The composition space in Figure 2 connects surrogates that include images of a crowd scene, a security camera and a disabled access symbol. The analyst uses combinFormation to organize surrogates in the composition space. She drags some surrogates into CRIS to develop new requirements for security access. Figure 3 shows a CRIS storyboard in ART-SCENE, created from surrogates retrieved and associated from the composition space of Figure 3.

More than one user can walk up to the security gates. The user can interact with the gate in different ways. Disabled access is provided, there are human security guards to provide assistance, and surveillance is in place, providing images of the faces of the registered user of an ID card.

During storyboarding the analyst can formalize new requirements in the VOLERE form. Figure 3 shows two functional requirements, one that specifies that the security guard shall view a picture of the registered user when an ID is swiped (based on images of banks of screens and images of people's faces), whilst the second specifies that the user will access to gate without actively having to swipe or use the card (based on images of a Smart card and fingerprint system). ART-SCENE supports further communication and traceability of requirements by linking each documented requirement and CRIS storyboard in the server-side database.

However we lacked empirical evidence that the integration could deliver requirements that, following Sternberg's definition, are more novel but still useful. Therefore a first exploratory evaluation was undertaken.

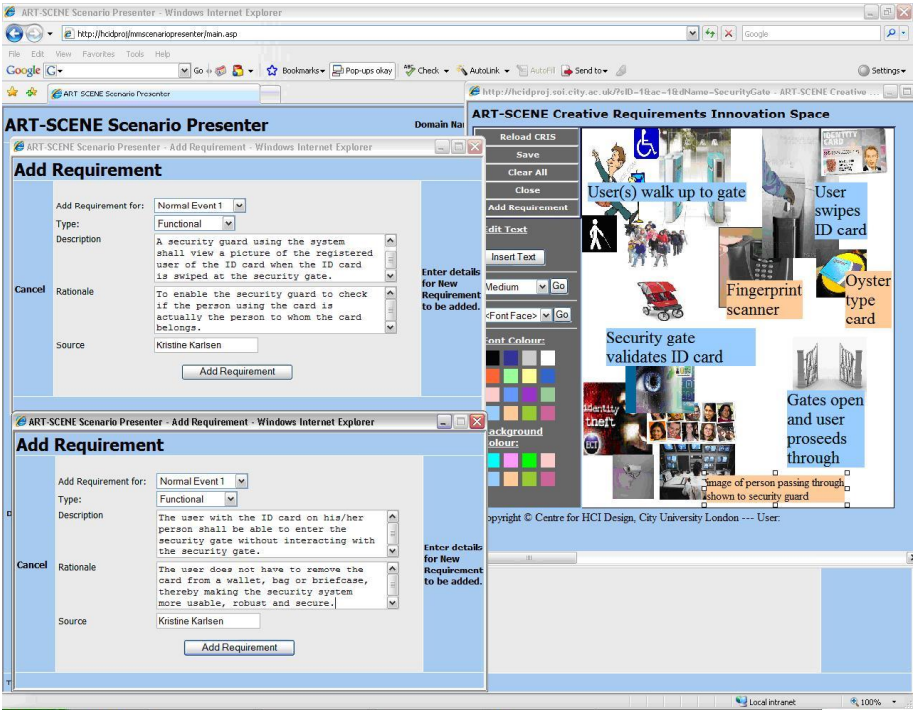


Fig. 3. A storyboard in CRIS, showing elements discovered with combinFormation, annotated with text (in blue) written within CRIS by an analyst. Two possible requirements generated from the CRIS storyboard are specified using VOLERE forms. One specifies the security guard shall view a picture of the registered user when an ID is swiped, whilst the second specifies that the user will be able to access to gate without actively having to swipe or use the card.

5 A First Exploratory Evaluation

Nine analysts worked individually with an environment comprising the ART-SCENE with CRIS and combinFormation (2006 version) tools (referred to ART-SCENE/cF) to generate requirements for the security access system scenario in Figure 1. Each had received training in walking through scenarios and writing VOLERE requirements. Each received a basic introduction to ART-SCENE, combinFormation and CRIS functions.

Requirements generated by the analysts were analyzed to explore 3 research questions based on Sternberg's definition of creativity:

Q1: Do analysts generate more requirements using ART-SCENE/cF than when using ART-SCENE-only?

Q2: Do analysts generate requirements that are more novel using ART-SCENE/cF than when using ART-SCENE-only?

Q3: Do analysts generate requirements using ART-SCENE/cF that would not have been generated using ART-SCENE-only?

The evaluation was in two parts of 20 minutes each. In the first, each analyst walked through the scenario with ART-SCENE-only to discover and document requirements for the security access system. Next, the experimenter seeded combinFormation with queries. The analyst continued the walkthrough in ART-SCENE with combinFormation and CRIS to discover and document requirements. Each analyst was then debriefed. Afterwards, a security expert rated the usefulness and novelty of all requirements generated by the 9 analysts.

All 9 analysts completed both parts of the evaluation and generated at least one CRIS storyboard each. combinFormation queries were simple and not tuned. During debriefings, all 9 analysts claimed that using ART-SCENE/cF had helped them to generate requirements not generated using ART-SCENE-only based on prompts from the composition space. Requirements totals by analyst are reported in Table 1.

Table 1. Totals of requirements generated by each analyst with ART-SCENE-only and with ART-SCENE/cF, and totals of security expert ratings of the usefulness and novelty of these requirements

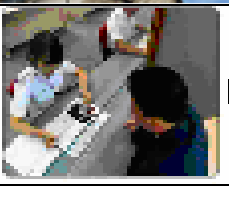
Analyst ID	ART-SCENE-only			ART-SCENE/cF		
	# of Requirements	Usefulness	Novelty	# of Requirements	Usefulness	Novelty
A1	16 (62%)	16 (100%)	0 (0%)	10 (38%)	10 (100%)	0 (0%)
A2	6 (67%)	5 (83%)	1 (17%)	3 (33%)	2 (67%)	0 (0%)
A3	13 (76%)	13 (100%)	0 (0%)	4 (24%)	4 (100%)	0 (0%)
A4	8 (62%)	8 (100%)	0 (0%)	5 (38%)	5 (100%)	0 (0%)
A5	14 (64%)	14 (100%)	0 (0%)	8 (36%)	8 (100%)	0 (0%)
A6	17 (63%)	17 (100%)	0 (0%)	10 (37%)	10 (100%)	0 (0%)
A7	10 (63%)	10 (100%)	3 (30%)	6 (38%)	6 (100%)	1 (17%)
A8	14 (61%)	14 (100%)	0 (0%)	9 (39%)	7 (78%)	3 (33%)
A9	7 (50%)	6 (85%)	1 (15%)	7 (50%)	6 (85%)	2 (29%)
Totals	**105 (63%)**	**103 (98%)**	**5 (5%)**	**62 (38%)**	**58 (94%)**	**6 (10%)**

On average, each analyst generated almost twice as many requirements with ART-SCENE-only as with ART-SCENE/cF. Reasons reported included generating the obvious requirements quickly with ART-SCENE-only, and the longer time needed to learn to use CRIS and select elements from combinFormation.

The security expert rated 98% of the ART-SCENE-only requirements as useful and 5% as novel, and 94% of the ART-SCENE/cF requirements as useful and 10% as novel, so although analysts generated fewer requirements when using ART-SCENE/cF, a higher percentage of these were rated as novel. Three of the 11 novel requirements were also rated as not useful for reasons that included *too much administration* and *not practicable due to costs*.

The 11 novel requirements – 5 generated with ART-SCENE-only and 6 with ART-SCENE/cF – were investigated. We attributed 4 of the 5 ART-SCENE-only requirements to alternative course events generated automatically in ART-SCENE. For example, the requirement *the system shall notify the user and alert an administrator when there is a malfunction with the card reader* in a response to the alternative course event *what if the Card Reader is unavailable or malfunctioning during this action?* One analyst (A7) specified 3 of these 5 novel requirements, suggesting that he exploited alternative course prompts for creative thinking more than the other analysts did.

Table 2. Eight requirements and their rationale generated by analysts using ART-SCENE/cF, and storyboard elements associated with these requirements. The security expert ranked all 8 as useful, and the first 5 as innovative.

Analyst A8 **Description**: If a toll is required, security should accept cash.		**Analyst A8** **Description**: It should be possible for the gate system to know who to expect at a certain time. The face of the person should be displayed on the monitor of the security desk when someone is expected.	
Analyst A8 **Description**: If user looks drastically different to when photographic ID was taken, security should be able to take new photos there and then. **Rationale**:		**Analyst A9** **Description**: When the user approaches the security gate, information will be displayed to them informing them on how to use the system.	
Analyst A9 **Description**: The security gates should have numerous entry points maximising the amount of people that can pass through at once.		**Analyst A9** **Description**: The system will include some CCTV aspect which will record who goes through at what time. it will be time linked with the recorded info in the card reader.	
Analyst A4 **Description**: Human assistance should be available in the event of a technical failure.		**Analyst A1** **Description:** The security gate is connected to a camera which can recognize and match features of a user to their ID card image/profile.	

During debriefings, analysts attributed only 1 of 6 ART-SCENE/cF requirements to alternative course events (analyst A7 again). The remaining 5 were attributed to surrogates in the analysts' storyboards shown in Table 2.

Results revealed individual differences between analysts. Analysts A8 and A9 generated the 5 innovative requirements associated with storyboard elements. For example, the requirement *if a toll is required, the security should accept cash*, was associated with an image of an *briefcase of cash*, whilst the requirement to *display the face of expected visitors* was associated with a *person's face on the retrieved magazine cover*. Similar associations were detected for the other 3 novel requirements, and with requirements rated as useful but not novel (Table 2).

All 9 analysts reported preferences for images over text, citing reasons like *images gave more impact* and *I could look at more pictures at the same time*.

The results provide tentative answers to our research questions. The answer to **Q1** was no, at least in a restricted time period. Using ART-SCENE/cF took more time than ART-SCENE-only, reducing the frequency and number of requirements that analysts generated. There is weak evidence to answer yes to **Q2**, because double the proportion of requirements generated with ART-SCENE/cF were rated as novel. However, introducing ART-SCENE/cF did not result in a step change in requirements creativity. Individual differences between analysts were a factor – all requirements rated as novel were generated by just one-third of the analysts. There is stronger evidence for answering yes to **Q3**. All analysts reported that ART-SCENE/cF prompted the generation of new requirements, both novel and otherwise, in connection with composition space surrogates.

Clearly there are threats to the validity of this first exploratory evaluation. Many of the threats limit the generality of the conclusions that can be drawn. A small number of analysts undertook the evaluation, which restricted our conclusions about the effectiveness of ART-SCENE/cF. The analysts had previous analysis experience within a given range, and our results cannot be applied to inexperienced analysts and analysts with over 10 years of analytic experience. Furthermore the results revealed important individual differences, with most creativity results generated by a small subset of the analysts. Finally the evaluation was undertaken in one problem domain – *secure gate access* – with small numbers of cF queries, and it is difficult to generalize the results to other domains, because the nature of the requirements discovered might be different and because different types of storyboard elements might be retrieved by cF.

Other threats to the validity of the evaluation were due to the design of the evaluation. The number of analysts available meant that a control group was not practical. We were unable to investigate the effect of the order of the two study tasks on requirements discovery, and increased exposure to the scenarios over time might have led to more discovered requirements. Likewise more training in combinFormation and CRIS might increase the volume and novelty of the requirements. In particular, if participants had known about how to express interest in combinFormation, this would have helped them to receive information more relevant to their tasks. combinFormation's fluid interface minimizes the cognitive effort required [8]. Likewise, knowledge of how to automatically generate a new search, using an existing surrogate in combinFormation, would have helped the analysts. Improving integration of the technologies is expected to improve the experience and results.

Nonetheless, the results reveal that the use of ART-SCENE/cF prompted analysts to generate requirements that otherwise might not have been generated. Evidence that only a minority of the ART-SCENE/cF requirements were novel is consistent with findings from earlier creativity workshops [12], in which stakeholders tend to generate useful requirements that are both novel and otherwise during periods of creative thinking.

6 Related Work

Little requirements research has addressed creative thinking directly. Brainstorming techniques and RAD/JAD workshops [3] make tangential reference to creative thinking. Most current brainstorming work refers back to Osborn's text [19] on principles

and procedures of creative problem solving (CPS). Examples of CPS activities include *the matrix*, which involves making lists then selecting items from each list at random and combining them to generate new ideas, and *parallel worlds*, which uses analogical reasoning to generate new ideas. However, there are no reported applications of the CPS model to requirements processes.

In the requirements domain, Robertson [20] argues that requirements analysts need to be inventors to bring about the innovative change in a product that gives competitive advantage. Such requirements are often not properties that a stakeholder would ask for directly. Nguyen et al. [18] observed that teams restructured requirements models at critical points when they re-conceptualize and solve sub-problems, triggered by moments of sudden insight. Mich et al. [15] report the successful use of the elementary pragmatic model from communication theory in a controlled environment to trigger combinatorial creativity during requirements acquisition. The RESCUE requirements process has ran numerous creativity workshops in domains from air traffic management to food information traceability [11, 12].

In creativity research, creativity support tools have been posited to support users to discover, explore, innovate and imagine. Schneiderman [21] reports that use of these tools to locate, study, review and revise can accelerate users' creative efforts. Search engines such as Google are important in such tools to locate information quickly. However Kules [16] reports that these search engines are more effective for retrieving information from well-defined queries than to support creative tasks with incomplete or ambiguous queries in often-unfamiliar domains. That said, by using more than ranked lists of search results, such as the hot space in combinFormation, we can support creativity by exposing users to information that will help the creative process. Greene [4] reported other important characteristics of creativity support tools, which include pain-free exploration and experimentation, supporting engagement with content to promote active learning, iteration, and collaboration. Future requirements tools will need some of these characteristics.

Whilst our work has sought to support individual creativity, much research focuses on collaborative creativity. Mamykina et al. [13] report research results that reveal the importance of social interactions, mentoring and collaboration in creative work, and Fischer & Giaccardi [2] talk of the need to sustain social creativity. Mamykina et al. [13] further report that effective collaboration involved 3 main activities – creative conceptualization, realization and evaluation. Future creativity tools that will support requirements processes might be expected to support at least these activities.

7 Creativity Support Tools for Requirements

We successfully integrated 2 tools to support people to think creatively about requirements. These tools utilize the Internet as a source of descriptions of domain events and situations that stimulate analysts and stakeholders to generate requirements that are more complete and novel.

The evaluation results have implications for improving the design of creativity support tools for requirements analysts. We need much better integration of creativity support tools with the tasks they intended to assist. Analysts' loss of efficiency while generating requirements is a concern. We can improve the efficiency of the

composition's stimulation of creative thinking in requirements generation. We hypothesize that using combinFormation's cool space as the storyboard, and then integrating combinFormation directly with server-side ART-SCENE will improve the experience and results in several ways. First of all, the number of windows will be reduced, thus increasing efficiency by reducing cognitive effort [5]. There is also an opportunity to invoke peripheral attention that minimizes the physical effort to see and interact with the composition being generated, the tools create the opportunity for the analyst to be stimulated by relevant information when it arises. The benefits of mixed-initiative composition on requirements generation will be increased. We will give users fluid mechanisms, next, for associating a combinFormation surrogate with an event in an ART-SCENE scenario, and with a requirement that the user has generated. We will also enable stakeholders working on the same scenario to share compositions.

We expected the analysts to generate one storyboard per scenario event of interest, but this did not happen. Although a lack of time to produce more than one storyboard was a factor, each storyboard included elements related to more than one scenario event. One possible reason was that elements retrieved from the Internet were more coarse grain than the actions, agents and objects described in the scenario events in ART-SCENE. One implication is to use composition to support the earlier use case authoring tasks, using surrogates to provide scaffolds with which to write the use cases.

The most important step is to derive queries automatically from ART-SCENE more effectively and pass them as seeds to the mixed-initiative composition space. The granularity of the queries can start with the generality of a scenario, and the shift to specific events and requirements. For software to perform this shifting automatically, it must model the user's attention in the context of using ART-SCENE to perform a task. This integration will be facilitated by combinFormation's services mechanism, through which the software functions as a composition visualization server that can respond to semantic messages. Thus, ART-SCENE will periodically send XML messages to the running cF over a network socket. The experimental results reveal that effective query formulation is essential to providing elements relevant to a requirements task. Better query formulation and integration between requirements specification and creativity support components has the potential to provide strong support for requirements tasks.

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