Awareness Checklist: Reviewing the Quality of Awareness Support in Collaborative Applications

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Abstract. A proposal of a method to assess awareness support is made. This proposal is intended for the use of collaborative applications developers at any time during development. It consists of a checklist. It is made with the inclusion of design elements obtained by the analysis of Quality Assurance ideas applied to collaborative systems. The proposal is illustrated with its use in two cases.

Key words: Awareness Inspection, Collaborative Applications.

1 Introduction

Awareness in its various types has always been considered a distinctive feature of collaborative systems when compared with other kinds of information systems [17]. Moreover, numerous studies have found awareness to be a very important component of a collaborative system [1-3]. Users' mobility increases the need for awareness since the collaboration environments typically change very often in this case.

We are particularly interested in assessing the awareness support in collaborative systems. An approach to do this study is by asking users about it. Questionnaires can be used for that purpose [4]. Alternatively, observation of people using the system can be useful to do this inquiry. Analysis of logging interactions [5] or video recordings [6] can then provide some answers to the evaluation of awareness support. Nevertheless, all these approaches require the participation of users.

Participation of users is not always possible or available at the time of evaluation [7]. For that case, we propose an awareness checklist which may be useful to system developers to assess their applications at various development stages. It can be argued a system's users are the best evaluators of it, which is true, but an alternative way may be required as a substitute or complement for the users' evaluation. The construction of the awareness checklist followed a process consisting of the following steps:

- Definition of awareness types.
- Definition of the design elements contributing to awareness that will be subject to the evaluation.
- Definition of correlations between design elements and awareness types with

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help from experts in collaborative systems development.

- Construction of the awareness checklist and summary tables.
- Validation of the awareness checklist in case studies.

The paper continues with a review of related work (Section 2); it starts with quality assurance, following with its relation to collaborative systems and then, with awareness. Section 3 deals with the awareness types. Then, Section 4 presents the proposed checklist. The use of this checklist in two cases is illustrated in Section 5. Section 6 concludes the paper with a summary of the obtained results.

2 Related Work

2.1 Quality assurance

Quality Assurance (QA) establishes the extent to which quality is being controlled in an organization [8]. QA typically applies control measures to an input-process-output production system, uncovering nonconformities in the system, avoiding wasted resources, while doing so at the least possible cost [9].

Hinckley [9] provides an insightful view over QA progress. Initial QA measures were based on loose judge inspections made by skilled craftsman in the production line. Later on, the adoption of gage instruments and standards has led to improved inspections and greater consistency. The emergence of Statistical Quality Control (SQC) brought a higher concern with predictable production models, adopting production samples and statistical methods to guide process adjustments [10].
Six-Sigma [11] has been developed to make drastic improvements in QA based on standards, measurement and analysis systems, and continuous quality improvement. Total Quality Management (TQM) also deals with a continuous optimization of business performance [12]. But its emphasis has shifted away from the technical towards broader organizational factors such as team development, learning and culture.

Of course most concerns with QA extend beyond the traditional industrial organizations and apply to software development. For instance, the Cleanroom Software Engineering approach adopts SQC to maintain software development under statistical control [13]. However, one main limitation of this approach is the process requires stable software specifications, a requirement that is hard to ensure in the software development field.

The Software Quality Function Deployment (SQFD) [14] method adopts the Six-Sigma's scorecard with a particular focus on customer needs. The origins of SQFD are rooted in the need to improve the quality of software design using precise control points throughout the development process and constant traceability of the customer requirements [15]. Thus the QA chart adopted by SQFD correlates customer-required quality functions with the product's engineering characteristics.

Formal Technical Reviews (FTR) [16] have been widely adopted in software engineering [17, 18]. They involve several people in a formal meeting during which a software artifact is presented, discussed and approved. FTR seek to identify defects and discrepancies in the software against plans, specifications, standards and best practices. They cover the whole software development life-cycle [19].

Johnson [20] analyzed the impact of software reviews on quality, showing that defects can be one or two orders of magnitude less costly to remove when found in initial development stages than after distribution to the customers. Moreover, software reviews were considered effective for discovering certain soft, but nevertheless costly, defects such as logically correct but poorly structured code.

2.2 Collaborative systems and quality assurance

Collaborative systems bring together two main organizational assets: technology and humans. The development of collaborative systems has for long been considered a special branch of software development concerned with: group characteristics and dynamics; communication, coordination and collaboration; conflict resolution and decision making; social context of work; and positive and negative effects of technology on tasks, groups and organizations.

QA is essential to ensure the quality of collaborative systems development. The problem now is that QA must assess a very wide range of factors related with multiple stakeholders (customers, managers, individual workers, formal and informal work groups), various domains of concern (business processes, goals, tasks, group well-being, culture) and multiple technology components (addressing various aspects of collaboration such as awareness). All in all, what distinguishes collaborative systems QA is indeed the need to evaluate its impact with an eclectic perspective.

Research shows that QA activities are difficult to accomplish when collaborative systems are involved. First, these systems are difficult to assess due to the complexity, cost and time involved [21]. Second, the assessments tend to be informal [22]. Finally, collaborative systems involve conflicting views that consider technology and its impact in organizations [21]. Nevertheless several assessment methods have been proposed; e.g. Herskovic et al. [21] identifies twelve methods and classifies them according to various criteria such as development status, scope, time span of the assessment and who participates in the assessment. Of these twelve methods, six require the participation of end users in several ways, like focus groups and observations. However, participation of end users in QA turns the process costly and quite difficult to manage.

Of the remaining six methods, three require modeling and analyzing the system functionality at a very low level of detail. And finally the remaining methods adapt the FTR approach to the specific characteristics of collaborative systems assessment. The methods are: Groupware Heuristic Evaluation (GHE) [23], Groupware Walkthrough (GW) [24] and Knowledge Management Approach (KMA) [25]. GHE defines a procedure for inspecting how a collaborative system conforms with eight heuristics that codify best practices in collaborative systems development [23]. GW entails stepping through task sequences to conceptually explore task goals, actions necessary to perform tasks, knowledge needed to accomplish tasks, and possible performance failures [24, 26]. Finally, KMA involves using a checklist to assess how the system helps knowledge circulation [25].

2.3 Quality assurance and awareness

We will now delve into the three FTR methods mentioned above to unravel how they address the quality of awareness support. As previously mentioned, GHE systematizes QA activities around a set of heuristics [23]. These heuristics define a checklist with qualities that a collaborative system should have. Some of these heuristics point towards the importance of awareness: (1) *Provide the means for intentional and appropriate gestural communication, (2) Provide consequential communication of an individual's embodiment, (3) Provide consequential communication of shared artifacts, (4) Management of tightly and loosely-coupled collaboration, (5) Allow people to coordinate their actions, and (6) Facilitate finding collaborators and establishing contact*.

GW involves stepping through task sequences to conceptually explore the actions users will perform. In order to formalize the analysis of the work context, Pinelle and Gutwin [24] defined the Mechanics of Collaboration, a set of seven collaboration primitives that makes up group dynamics [26], that include *monitoring* as an explicit concern with awareness.

KMA differs from the other techniques. Instead of focusing on the essential features of collaboration support, KMA seeks to evaluate how organizations are able to manage their knowledge while using collaborative systems [25]. It focuses on analyzing situations where knowledge does not flow correctly. A checklist is provided with a set of questions that expose missing links, black holes and points of congestion in information flows. Awareness is indirectly considered in this approach.

All in all, we observe concern with awareness is present in these FTR methods but diluted among many other issues. Thus we find here an opportunity to develop a FTR method specifically concerned with reviewing the quality of awareness support.

2.4 Other methods to evaluate quality of awareness support

Convertino et al. [27] developed a laboratorial method to assess activity awareness in controlled settings. This is the only work we found that explicitly develops a QA technique for awareness in collaboration systems. The method is based on collaboration scenarios drawn from field studies and assessed during laboratory experiments using questionnaires, interviews and observations. Unfortunately this approach requires significant time and effort to prepare and run the experiments. Furthermore, it requires a mature definition of the system functionality, which makes it difficult to apply at early design stages.

QA of awareness has also been a major issue in a quite different research field: cognitive systems engineering. The main reference in this area is the work by Endsley et al. on situation awareness [28-30]. Situation awareness is the capability to understand a series of events at three different levels [28]: in level 1, training and experience direct attention to critical elements in the environment; level 2 integrates elements that aid understanding the meaning of critical elements; and level 3 considers understanding the possible future scenarios. Endsley developed the Situational Awareness Global Assessment Technique (SAGAT) [31] to assess the users' situation awareness. SAGAT uses questionnaires to inquire users about perception, comprehension and projection issues in situations where working activities have been interrupted [32]. The main application areas of SAGAT deal with complex activities like piloting. Other techniques, like thinking aloud, filling mini situation reports and probing questions have been used to assess situation awareness [33]. All these techniques involve end users in the assessment process.

Still regarding the cognitive perspective, Zhang and Hill [34] developed a pattern-based approach to situation assessment. The approach uses spatial relationships in synthetic workspaces to represent the situation. Situation assessment is based on two major steps: data organization for perception (e.g. clustering) and matching against situation templates, which have to be predefined.

2.5 Summary

Figure 1 summarizes our analysis of the related literature. The discussion on Quality Assurance brings forward the TQM movement, which originated new assessment methods based on participation and collaboration. Of those methods, FTR take a prominent place in software development. Collaborative systems are a specialized sector within software development, which has lead to specialized FTR methods such as GHE, GW and KMA. Our analysis of these methods uncovered there was little coverage of awareness. This opens up the opportunity to develop a FTR method specifically focused on awareness assessment. Beyond the FTR context, we have only found one technique in the literature whose major concern is awareness assessment. However, the proposed approach requires significant effort and time to accomplish; and it is difficult to apply at early design stages.

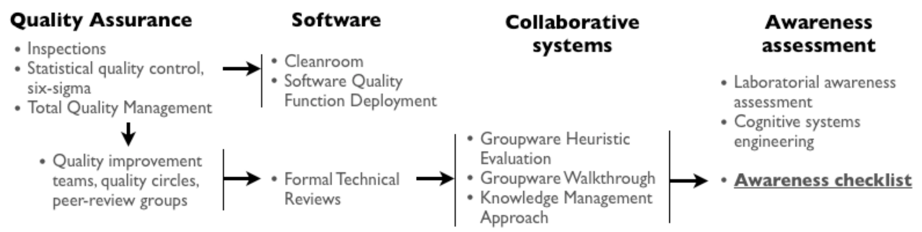

Fig. 1 - Summary view of awareness assessment.

3 Awareness Elements

The *time/place* relationship is the most prevalent subject related to collaborative applications. The time/place map proposed by Johansen et al. [35] is founded upon the discussion by DeSanctis and Gallupe [36] on the support to remote and local groups. The distinctions between same-place, different-place and any-place do not only highlight spatial issues but also the actual extent members have to access the group. In particular, the members located at different places are conditioned by infrastructure factors like network connectivity, data distribution, throughput, bandwidth and message delays. Some variations of the time/place map have been elaborated to encapsulate these factors [37]. They expand the place dimension to three categories, considering co-located, virtual co-located and remote places.

Social theorists have also regarded the degree of communication afforded by technology as a fundamental constraint to collaboration. Studies of media richness [38] and media naturalness [39] show that communication mediated by technology loses several important features such as nonverbal cues, rapid feedback and arousal. In this line of reasoning, the notion of place is fundamental to adapt the medium to the group and task. The time/place differences define collaboration awareness as the perception of temporal and spatial structures in a group of peers [40, 41].

Several authors extend the notion of place, linked above to infrastructural issues, to the notion of space [42, 43]. Spaces provide additional context to places such as physical location, topology and mobility. We may identify five types of space. The first one is the *geographical space*, which introduces geographical relationships such as location, distance and orientation. Dix et al. [44] further characterized location as either being Cartesian or topological.

Then we have the *physical space*, which mainly concerns mobility. Mobility has been categorized in wandering, visiting and traveling [45]. Dix et al. [44] proposed another taxonomy: fixed, mobile, autonomous, free, embedded and pervasive. Hazas et al. [46] discuss location awareness as the means to determine physical location using various types of sensing technology such as GPS and RFID. Hazas et al. [46] also make the distinction between physical and semantic locations such as rooms, floors and buildings.

Cheverst et al. [47] studied the relationships between physical spaces, mobility, location awareness and location services to derive important requirements such as flexibility, visibility and context-sensitivity. Davis also [48] analyzed the challenges posed by mobility and information access, including the removal of time/space constraints to communication and knowledge work, improved access to decision makers and increased ability to receive and process information.

The third type of space we consider is the *virtual space*. Rodden [49] developed the notion of virtual space as a collection of computer-supported interactive spaces. Many collaborative applications offer various types of virtual spaces, including virtual meeting rooms, media spaces and Collaborative Virtual Environments [50].

Virtual spaces have a conceptual topology, they are interactive, shared, malleable, populated and may be navigated. Interaction involves the dissemination of interaction and navigation information to the group members, thus constructing what Rodden has coined context awareness [49]. Rodden also proposed a conceptual model of context awareness in virtual spaces using focus and nimbus. Focus and nimbus are subspaces that map the attention and presence of elements in spaces. Also related with context awareness, we find the distinction between private and public spaces, the former pertaining to things and actions belonging to one single individual and the latter shared among a group [51, 52].

Navigation in virtual spaces is not necessarily spatial but may also be logical. For instance, the rooms-metaphor defines navigation in virtual spaces like discussion forums [53] that are not spatially organized but rather organized according to a set of interests. Virtual spaces may assume complex structures, such as clusters, stacks, lists, tables and rooms [54]. Users should then be able to navigate these structures and obtain context awareness. Collaborative visualization, as an enabler of collaboration, is naturally a major challenge to consider in virtual spaces [52, 55]. Collaborative visualization involves data exchange, shared control and dynamic interaction [56].

Another type of space we identify is the *social space*. Dourish [43] and Brewer and Dourish [57] proposed social spaces as adequate to understand broader issues related to social practice and context. In this respect, social places combine geographical, physical and virtual affordances with social interaction, cultural meaning, experience and knowledge. Dourish [58] also proposed the notion of embodied interaction to account for the embedded relationships between social and the other spaces.

The final type of space we consider is the *workspace*. According to Snowdon et al. [50], a workspace is a container of places with ongoing activities. We may distinguish two different aspects of workspaces. On the one hand, workspaces may organize activities according to logical sets. A group editor is a good example of this type of workspace, as it serves to organize activities like writing and revising, while maintaining a coherent view of the whole [59]. On the other hand, workspaces also introduce geography as an important context for working activities [56, 60, 61].

Liechti [62] studied the relationship between context and workspace and proposed peripheral awareness as the capability to understand the activities being carried out by others nearby one's place. Gutwin and Greenberg [63] expanded this view to account for the whole space, defining workspace awareness as the understanding of another person's interactions in a shared workspace using a basic set of questions: who, what, where, when, and how.

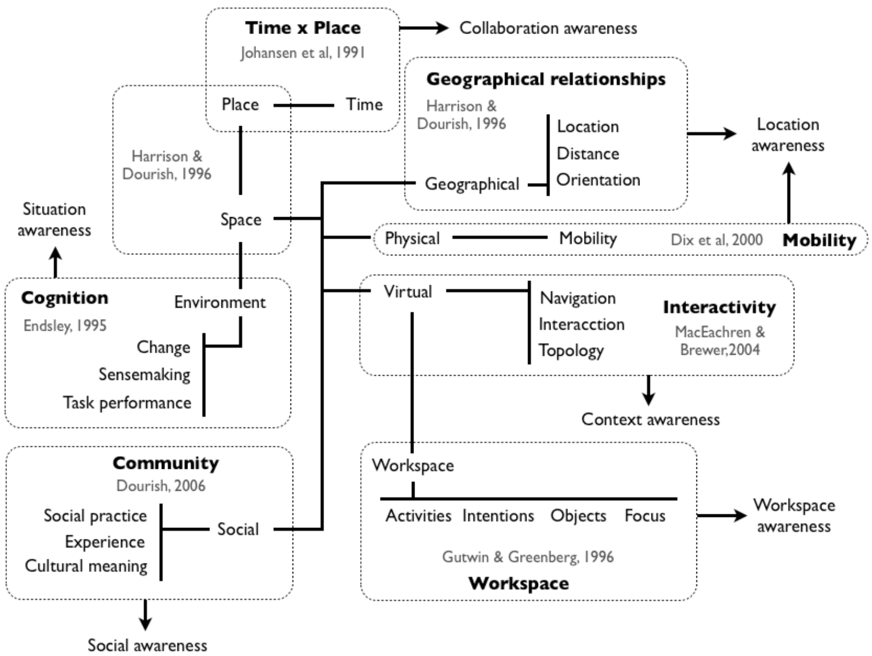

Fig. 2 - Overview of main awareness elements.

According to Gutwin et al. [64], workspace awareness is a specialization of a more broad concept designated *situation awareness*. Endsley [28, 29] defined situation awareness as the understanding of what is going on in the working environment with the purpose of performing tasks effectively. Endsley defined three levels of situation awareness: perception of elements in the current situation, comprehension of current situation and projection of future status.

Jensen [65] combined situation awareness with sensemaking, a theory developed by Weick [66, 67] to understand the relationships between environmental changes and organizational responses. Sensemaking is defined as the capability to create order and make retrospective sense of what occurs through the articulation of several cognitive functions like perception, interpretation and anticipation of events [66]. Cecez-Kecmanovic [68] highlighted that sensemaking emerges from individual, coordinated and collaborative efforts.

Figure 2 presents an overview of the awareness elements that we have identified: time x place, space (geographical, physical, virtual and social), workspace and situation awareness, as well as their main aspects and the types of awareness they support.

4 The Awareness Checklist

In Section 3 we laid out a comprehensive overview of the main awareness elements we find in collaborative systems. We identified seven types of awareness: time x place, geographical space, physical space, virtual space, social space, workspace, and situation awareness. We also uncovered several design elements that influence or contribute to awareness support. The total number of design elements discussed in the previous section is 77. To make this a manageable list, we organize the design elements in the 14 categories shown in Table 1.

Table 1. Main design elements influencing awareness.

	Design categ.	**Design elements**
1	Accessibility	Same place, different place, any place, co-located, virtually co-located, remote
2	Communication	Synchronous, asynchronous, network connectivity, message delivery, network management
3	Spatiality	Cartesian locations, topological locations, distances, orientation, focus/nimbus
4	Mobility	Wandering, visiting, traveling, fixed, mobile, autonomous, independent, embedded, pervasive
5	Physicality	Physical constraints, physical places, physical topology, physical attributes
6	Navigation	Viewports, links, radar views, teleports
7	Virtuality	Private, group, public, data access privileges, concurrency control, floor control, version control, virtual constraints, virtual places, virtual topology, virtual attributes
8	Membership	Participants, roles, activities, privileges, group history
9	Attention	Eye-gaze orientation, body orientation, voice filtering, portholes/peepholes
10	Task	Who, what, where, when, how, task history
11	Interaction	Feedback, feedthrough, backchannel feedback
12	Interdependence	Parallel activities, coordinated activities, mutually adjusted activities, loosely coupled, tightly coupled
13	Internalization	Events, actions, resources, critical elements, meaning, future scenarios
14	Externalization	Individual cognition, distributed cognition, team cognition

In Table 2 we define the relationship between design and awareness elements.

These relationships are derived from the analysis presented in Section 3. However, during this research, we observed that these relationships are more complex than what Table 2 implies. For instance, the different-place design element has main influence on “time x place” awareness. However, a different-place design also influences negatively workspace awareness, especially because communication channels tend to be a limiting factor. Therefore we may say that accessibility directly influences “time x space” awareness and indirectly influences workspace awareness.

Table 2. Main relationships between design and awareness elements.

	Type of awareness	Design categories
1	Time x place	Accessibility, communication
2	Geographical space	Spatiality
3	Physical space	Mobility, physicality
4	Virtual space	Navigation, virtuality
5	Social space	Membership, attention
6	Workspace	Task, interaction, interdependence
7	Situation	Internalization, externalization

To find out these indirect relationships, we requested five experts in collaborative technology to define the relationships between the 77 design elements and the seven types of awareness. These experts were supplied with a table having the strong relationships shown in Table 2 and were requested to define additional moderate and weak relationships. To calculate the correlations, the strong, moderate and weak relationships were empirically given the values 4, 2 and 1, respectively. The accumulated correlations obtaining a value equal or below 2 were zeroed.

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Acessibility						Communication					Spatiality				
Design elements / Awareness categories	Same place	Different place	Any place	Co-located	Virtually co-located	Remote	Synchronous	Asynchronous	Network connectivity	Message delivery	Network management	Cartesian locations	Topological locations	Distances	Orientations	Focus/nimbus
Time x Place	6,1	6,1	6,1	6,1	6,1	6,1	7,3	7,3	7,3	7,3	7,3		1,1	1,5		
Geographical space			2,4			2,4						14,3	14,3	14,3	14,3	14,3
Physical space			1,1			1,8						1,3	1,3	1,7	1,7	
Virtual space					1,5		1,3		1,7	1,7						2,2
Social space					0,7		1,8	1,2		1,5	0,9					1,5
Workspace	0,6	1,3	0,9	0,6	0,7	1,1	1,8	1,8	0,9	1,3						
Situation		1,3	1,1		0,9	1,3	1,5	1,5	1,0	1,3			1,0			

Column #	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Mobility									Physicality				Navigation			
Design elements / Awareness categories	Wandering	Visiting	Travelling	Fixed	Mobile	Autonomous	Independent	Embedded	Pervasive	Physical constraints	Physical places	Physical topology	Phyisical attributes	View ports	Links	Radar views	Teleports
Time x Place												1,4		1,4	1,4		
Geographical space	2,0	1,2	2,8		2,4										2,7		
Physical space	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,8	10,8	10,8	10,8	10,8				
Virtual space														10,9	10,9	10,9	10,9
Social space	0,7	0,7	0,7			0,5								1,5		1,5	1,5
Workspace	0,7	0,5	0,5		0,4											1,1	
Situation	0,6				0,9	0,6		0,4		1,3	1,3			1,3		1,3	1,0

Column #	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
	Virtuality											Membership					Attention			
Design elements / Awareness categories	Private objects	Group objects	Public objects	Data access privileges	Concurrency control	Floor control	Version control	Virtual constraints	Virtual places	Virtual topology	Virtual attributes	Participants	Roles	Activities	Privileges	Group history	Eye-gaze orientation	Body orientation	Voice filtering	Porholes, peepholes
Time x Place																				
Geographical space																				
Physical space																				
Virtual space	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0						1,6			
Social space	0,4	0,5	0,5	0,4	0,4							5,9	5,9	5,9	5,9	5,9	7,4	7,4	7,4	7,4
Workspace		0,7	0,5			0,6	0,4	0,4	0,4	0,4	0,4	2,0	1,8	2,0	1,1					
Situation		0,5	0,3		0,3							1,5	1,5	1,5		1,0				1,3

Column #	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	Task						Interaction			Interdependence						Internalization						Externaliz.		
Design elements / Awareness categories	Who	What	Where	When	How	Task history	Feedback	Feedthrough	Backchannel	Individual activities	Paralell activities	Coordinated activities	Mutually adjusted activities	Loosely coupled	Tightly coupled	Events	Actions	Resources	Critical elements	Meanings	Future scenarios	Individual cognition	Distributed cognition	Team cognition
Time x Place	0,9		1,5	1,8			2,4	2,4		0,9	0,9	1,2	1,2	0,9	1,2	1,2	1,2					2,4		
Geographical space			2,4				4,8	3,6										1,8						
Physical space		1,4		1,1	1,1													1,1						
Virtual space																1,1	1,5							
Social space	1,5	1,0					2,5	2,5	2,5	0,7	1,0	1,0	1,0	0,7	1,0	0,7	1,2		0,7	1,0			2,5	2,5
Workspace	3,7	3,7	3,7	3,7	3,7	3,7	7,4	7,4	7,4	3,7	3,7	3,7	3,7	3,7	3,7	1,3	0,9	0,9				1,9	1,5	1,5
Situation	1,7	1,7	1,7	1,7	1,7	1,3	1,7	2,1	2,1			1,7	1,7	0,6	1,7	4,3	4,3	4,3	4,3	4,3	4,3	8,5	8,5	8,5

Fig. 3 – Correlations matrix with moderate and weak relationships expressed by the experts.

The correlations were then normalized in two ways: (1) normalize the impact of each design category in the awareness score, avoiding that design categories with a higher number of design elements have more impact on the awareness scores; and (2) normalize the awareness scale so the sum of all correlations for a given awareness category is 100%. The correlations matrix is shown in Figure 3.

We constructed the awareness checklist based on the elements summarized in Tables 1-2 and Figure 3. The checklist is also inspired on the House of Quality (HoQ), a basic QA map used by many organizations to correlate software implementations to quality items [69]. In our case, we correlate 77 design elements with seven awareness categories. The correlations adopt a qualitative classification that is also common in the HoQ: strong positive (+2); positive (+1); uncorrelated (0); negative (-1) and strong negative (-2).

The checklist is shown in Figure 4. After completion, it automatically reports the applications' positive and negative scores (Figure 5). The scores are determined in the following way:

1. For each awareness category, every design element in the checklist that received a positive assessment (+2 or +1) is multiplied by the corresponding correlation expressed in the correlations matrix for that awareness category.
2. The same operation is executed for the negative assessments (-2 or -1).
3. For each awareness category, the positive score is obtained by adding the adjusted results obtained in step 1, multiplied by a 0.5 factor. This allows normalizing the scores on a [0-100] scale.
4. For each awareness category, the negative score is obtained by adding the adjusted results obtained in step 2, multiplied by a -0.5 factor, which again normalizes the scores on a [0-100] scale.

Row #		Design elements	Assessment
1	Acessibility	Same place	Θ
2	Acessibility	Different place	Θ
3	Acessibility	Any place	Θ
4	Acessibility	Co-located (face-to-face)	Θ
5	Acessibility	Virtually co-located (high-quality video/audio links)	⊗
6	Acessibility	Remote	O
7	Communication	Synchronous (same-time)	O
8	Communication	Asynchronous (different-time)	Θ
9	Communication	Network connectivity	O
10	Communication	Message delivery	Θ
11	Communication	Network management	Θ
12	Spatiality	Cartesian locations	Θ
13	Spatiality	Topological locations	O
14	Spatiality	Distances	O
15	Spatiality	Orientations	O
16	Spatiality	Focus/nimbus (center of activity)	O
17	Mobility	Wandering	Θ
18	Mobility	Visiting (e.g. others' offices)	Θ
19	Mobility	Travelling	⊗
20	Mobility	Fixed	⊗
21	Mobility	Mobile (human control)	⊗
22	Mobility	Autonomous (own control)	Θ
23	Mobility	Independent (from other devices)	Θ
24	Mobility	Embedded (in other devices)	⊗
25	Mobility	Pervasive (throughout the environment)	X
26	Physicality	Physical constraints	⊗
27	Physicality	Physical places	X
28	Physicality	Physical topology	⊗
29	Physicality	Phyisical attributes	⊗
30	Navigation	Viewports (over workspace)	⊗
31	Navigation	Links (to other places)	⊗
32	Navigation	Radar views (over workspace)	O
33	Navigation	Teleports (to others' foci)	⊗
34	Virtuality	Private objects	Θ
35	Virtuality	Group objects	Θ
36	Virtuality	Public objects	Θ
37	Virtuality	Data access privileges	Θ
38	Virtuality	Concurrency control	⊗
39	Virtuality	Floor control (channel's access)	⊗
40	Virtuality	Version control	Θ
41	Virtuality	Virtual constraints (e.g. editing)	⊗
42	Virtuality	Virtual places	⊗
43	Virtuality	Virtual topology (e.g. rooms)	⊗
44	Virtuality	Virtual attributes	⊗
45	Membership	Participants	Θ
46	Membership	Roles	Θ
47	Membership	Activities	Θ
48	Membership	Privileges	Θ
49	Membership	Group history	Θ
50	Attention	Eye-gaze orientation	⊗
51	Attention	Body orientation	⊗
52	Attention	Voice filtering (controlled by distance or orientation)	⊗
53	Attention	Porholes, peeholes (to others' working environment)	⊗
54	Task	Who	Θ
55	Task	What	Θ
56	Task	Where	Θ
57	Task	When	Θ
58	Task	How	Θ
59	Task	Task history	⊗
60	Interaction	Feedback (individual inputs)	O
61	Interaction	Feedthrough (group inputs)	O
62	Interaction	Backchannel (response tokens)	O
63	Interdependence	Individual activities	Θ
64	Interdependence	Paralell activities	Θ
65	Interdependence	Coordinated activities	O
66	Interdependence	Mutually adjusted activities	X
67	Interdependence	Loosely coupled	Θ
68	Interdependence	Tightly coupled	⊗
69	Internalization	Events	O
70	Internalization	Actions	Θ
71	Internalization	Resources	Θ
72	Internalization	Critical elements (e.g. ideas, problems)	⊗
73	Internalization	Meanings	⊗
74	Internalization	Future scenarios	⊗
75	Externaliz.	Individual cognition	⊗
76	Externaliz.	Distributed cognition	⊗
77	Externaliz.	Team cognition	⊗

Fig. 4 – COIN awareness checklist (Θ=2; O=1; X=-1; ⊗=0).

The awareness checklist is used during FTR in the following way. The reviewers check the implementation against the 77 design elements. Positive relationships indicate the implementation contributes to realize the design element, while negative relationships indicate the implementation is detrimental to the respective design requirement.

Then the reviewers analyze the results in the awareness report. The positive and negative scores are discriminated according to the 14 design categories and 7 awareness categories. Overall scores for each awareness category are also shown. It should be noted the most positive outcome that may be achieved in one awareness category is having 100 positive and 0 negative scores, while the most negative outcome is having 0 positive and 100 negative scores.

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Acessibility						Communication					Spatiality				
Design elements / Awareness categories	Same place	Different place	Any place	Co-located	Virtually co-located	Remote	Synchronous	Asynchronous	Network connectivity	Message delivery	Network management	Cartesian locations	Topological locations	Distances	Orientations	Focus/nimbus
Positive																
Time x Place	6	6	6	6		3	4	7	4	7	7		1	1		
Geographical space			2			1						14	7	7	7	7
Physical space			1			1						1	1	1	1	
Virtual space							1		1	2						1
Social space							1	1		1	1					1
Workspace	1	1	1	1		1	1	2	0	1						
Situation		1	1			1	1	2	1	1			1			
Negative																
Time x Place					6											
Geographical space																
Physical space																
Virtual space					1											
Social space					1											
Workspace					1											
Situation					1											

Column #	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Mobility									Physicality				Navigation			
Design elements / Awareness categories	Wandering	Visiting	Travelling	Fixed	Mobile	Autonomous	Independent	Embedded	Pervasive	Physical constraints	Physical places	Physical topology	Physical attributes	Viewports	Links	Radar views	Teleports
Positive																	
Time x Place																	
Geographical space	2	1															
Physical space	5	5				5	5										
Virtual space																5	
Social space	1	1				0										1	
Workspace	1	0														1	
Situation	1					1										1	
Negative																	
Time x Place												1		1	1		
Geographical space			3		2										3		
Physical space			5	5	5			5	2	11	5	11	11				
Virtual space														11	11		11
Social space			1											1			1
Workspace			0		0												
Situation					1			0		1	1			1			1

Column #	34	35	36	37	38	39	40	41	42	43	44
	Virtuality										
Design elements / Awareness categories	Private objects	Group objects	Public objects	Data access privileges	Concurrency control	Floor control	Version control	Virtual constraints	Virtual places	Virtual topology	Virtual attributes
Positive											
Time x Place											
Geographical space											
Physical space											
Virtual space	4	4	4	4			4				
Social space	0	1	1	0							
Workspace		1	1				0				
Situation		0	0								
Negative											
Time x Place											
Geographical space											
Physical space											
Virtual space					4	4		4	4	4	4
Social space					0						
Workspace						1		0	0	0	0
Situation					0						

Column #	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
	Membership					Attention				Task						Interact.		
	Participants	Roles	Activities	Privileges	Group history	Eye-gaze orientation	Body orientation	Voice filtering	Porholes, peeholes	Who	What	Where	When	How	Task history	Feedback	Feedthrough	Backchannel
Positive: Time x Place										1		2	2			1	1	
Geographical space												2				2	2	
Physical space											1		1	1				
Virtual space																		
Social space	6	6	6	6	6					1	1					1	1	1
Workspace	2	2	2	1						4	4	4	4	4		4	4	4
Situation	2	2	2		1					2	2	2	2	2		1	1	1
Negative: Time x Place																		
Geographical space																		
Physical space																		
Virtual space						2												
Social space						7	7	7	7									
Workspace															4			
Situation									1						1			

Column #	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	Interdependence						Internalization						Externaliz.		
	Individual activities	Paralell activities	Coordinated activities	Mutually adjusted activities	Loosely coupled	Tightly coupled	Events	Actions	Resources	Critical elements	Meanings	Future scenarios	Individual cognition	Distributed cognition	Team cognition
Positive: Time x Place	1	1	1		1		1	1							
Geographical space									2						
Physical space									1						
Virtual space							1	1							
Social space	1	1	0		1		0	1							
Workspace	4	4	2		4		1	1	1						
Situation			1		1		2	4	4						
Negative: Time x Place				1		1							2		
Geographical space															
Physical space															
Virtual space															
Social space				0		1				1	1			2	2
Workspace				2		4							2	1	1
Situation				1		2				4	4	4	9	9	9

Positive scores
70
58
30
32
50
64
39

Negative scores
14
8
59
60
43
18
50

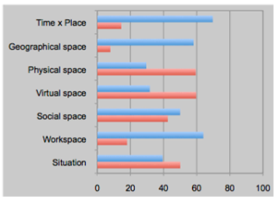

Fig. 5 – COIN awareness report.

5 Examples of Use

This section briefly presents the inspection of two collaborative applications. The first application is MobileMap (Figure 6), which supports firefighters attending regular emergencies in urban areas. The second application is COIN (Figure 8), which supports construction inspectors reviewing physical infrastructures in construction sites.

Fig. 6. MobileMap user interface

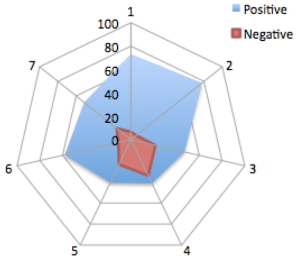

Fig. 7. MobileMap scores

Fire truck drivers use MobileMap to guide themselves to their destination. The user interface presents two arrows pointing from the current location (Figure 6): the white arrow indicates the direction in which the fire truck is moving; and the black one shows the direction in which the truck should move to get to the emergency place. This simple interface helps arriving faster to emergency sites (ref. omitted).

Two developers individually inspected MobileMaps using the awareness checklist. Figure 7 shows the obtained average scores. Analyzing these results, we may see that virtual space awareness (category 4) is the most problematic type of awareness. This should raise the developers' attention to understand if this type of awareness is required to guide the fire truck and realize how the application could better support the firemen.

Figure 8 shows the COIN user interface, which construction inspectors use to annotate digital maps related to construction projects. These annotations are done in the field and used in the office to schedule maintenance tasks to sub-contractors. Two developers also inspected COIN. Figure 9 shows the obtained results. COIN obtained low positive scores in physical and virtual space awareness (items 3 and 4). Situation awareness (item 7) also seems problematic because of the high negative scores.

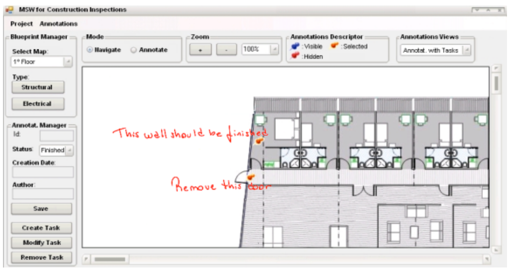

Fig. 8. COIN main interface

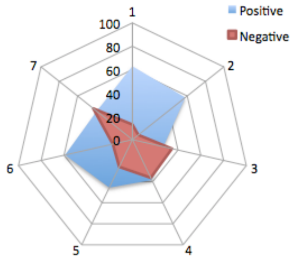

Fig. 9. COIN evaluation results

The situation with physical awareness in the two applications is particularly interesting to observe. In these applications, mobility and location awareness play an important role; however, it is not well supported. In the case of COIN, mobility support is quite appropriate but location support seems insufficient. On the contrary, in the case of MobileMap, location support seems to be appropriate. However, there is insufficient support to mobility. That is the main reason why the negative scores are high. Developers have here the chance to improve collaboration support by identifying the awareness categories and specific design elements requiring additional support. In that sense, the proposed checklist is an important instrument helping on the identification of deficiencies in collaborative applications.

6 Conclusions

Awareness is an important component of collaborative systems that helps users to conduct interaction processes. In this paper, we have studied the assessment of awareness support starting with the basic concepts of quality assurance of software systems.

We developed an awareness checklist helping developers inspect the quality of awareness support in collaborative applications. The checklist is founded on quality assurance principles and especially on the formal technical review technique. The checklist items were defined based on a comprehensive overview of awareness research that allowed us to identify 77 design elements contributing to seven different types of awareness. Of course, the developer is not forced to require all these design elements to be present in a certain system; the developer can use this checklist together with the possible mechanisms intended to provide awareness pondering the benefit of a certain awareness element with the estimated cost to the users in terms of information overload.

The correlations between design and awareness elements were defined according to theory and practice, incorporating the views of several experts in collaborative systems development. The awareness checklist allows obtaining a fast assessment of the quality of awareness support supplied by an application by simply inquiring about how effectively some key design elements have been supported. The awareness checklist serves to obtain positive and negative scores, both contributing to inform developers about which design areas require major interventions. The awareness checklist also serves to define quality metrics, control the development processes and benchmark various applications. The awareness checklist has already been used to inspect two collaborative applications. The obtained results indicate the checklist is adequate to formally review awareness support.

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