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Personal Requirements Engineering

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1. Introduction

The field of requirements engineering has grown up around a model of one-size-fits-all. Exemplar systems are either in the form of productivity tools for a mass population, or of one-off systems for high-assurance problems [Feather et al, 1997]. We have run into a difficulty with this model. For our particular application, delivering software tools to those with a traumatic brain injury (TBI), the one-size-fits-all model breaks down; TBI users require customized systems. It is not enough to attempt to deliver "the TBI-user system", i.e., to do a large study of the TBI population and attempt to come up with a single system that meets all their needs. Instead, we must focus on each individual's needs. This requires a new approach to requirements engineering. We need a means of (1) *assessing* the requirements of an individual, (2) *delivering* a system that meets an individual's requirements, and (3) *monitoring* the deployed system over time to watch for a misalignment of needs and what is delivered. Our research addresses these three issues. It hypothesizes that we can define an assessment technique that deals with individual needs, that we can then use the results to produce custom software (and other system components) that meet the needs, and that we can monitor at runtime for requirements compliance.

We chose to focus on email as our first application with the TBI population. It is an application that many of us take for granted, but one that is currently beyond reach of most TBI survivors. We have spent the last 2 years studying the domain, working with TBI survivors and domain experts to scope the problem. One conclusion that is clear is that email is a composite system problem [Fickas&Helm, 1992]. While it is natural to focus on the TBI user and his or her email client (GUI and associated software) as the major concern, we have found it is just as important to include the other components of the "email system", including the various human agents (family, friends, careproviders, clinicians), computing hardware available, internet connectivity available, the hardware components in the user's living environment (e.g., TV, phone), and software agents that may assist to mitigate impairments that impinge on email use. We have attempted to define a personal requirements engineering process that treats email for TBI users as a composite system problem. It is *personal* because our lab findings indicate that delivered systems must be tailored, if not fully custom [Sohlberg et al, 2000a]. This paper focuses on the first of the three challenges, working with individuals to assess their skills and needs. We will also briefly describe our pilot efforts delivering custom solutions and monitoring those solutions over time.

2. A more detailed characterization of the problem

The authors are part of a larger group (www.think-and-link.org) that is studying a specific set of tools to facilitate social interaction over the internet for persons with cognitive-linguistic impairments due to traumatic brain injury. Our goal is to reduce social isolation for TBI survivors. Our approach is to build communication tools that allow TBI survivors to both stay in contact with old friends and meet new friends. The first tool we are studying is email. Before discussing the email usability problems encountered by TBI survivors can entail, we offer some background information relevant to the TBI population.

Prevalence estimates range from 2.5 to 6.5 million individuals living with the consequences of TBI, with that number growing with advances in medical procedures at the scene of the accident, in emergency medical care, and in neurosurgery. Many of these individuals are left with long-lasting alterations in social, behavioral, physical, and cognitive functions. The incidence rates for the most severe traumatic brain injuries are higher than those for spinal cord injury, multiple sclerosis, cerebral palsy, and muscular dystrophy combined (BIA, Inc., 2000). A typical TBI survivor is a young to mid-life adult, living either in (a) government-assisted housing, (b) with their family, or (c) in rarer cases, in their own house or apartment. Survivors are universally afflicted with social isolation [Zencius &Wesolowski, 1999]. The brain injury can have as cause one or more of the types listed in figure 1. (Note that we will use material directly from our RE process documents [Sohlberg et al, 2000b] for some of our figures. Figure 1 is an example. It is part of the information we gather about an individual's injury.)

☐$_1$ *illness/tumor*	☐$_6$ *weapons accident*
☐$_2$ *motor vehicle crash*	☐$_7$ *fall*
☐$_3$ *assault/abuse*	☐$_8$ *drugs/medications*
☐$_4$ *pedestrian/ bicycle accident*	☐$_9$ *heart attack*
☐$_5$ *drowning*	☐$_{10}$ *stroke/aneurysm*

Figure 1. Causes of TBI

TBI is part of a larger group of acquired neurological disorders (e.g., dementia) that share some common cognitive-linguistic impairments, such as memory loss and language impairment (e.g., aphasia). TBI can be differentiated both on the demographics of survivors (younger, different interests) and the highly individualized nature of impairments that each survivor experiences. As an overview, figure 2 describes those impairments.

Primary cognitive impairment:

☐$_1$ memory	☐$_5$ attention	☐$_8$ initiation
☐$_2$ planning/organization	☐$_6$ problem solving	☐$_9$ visuoperceptual processing
☐$_3$ language(reading/writing)	☐$_7$ impulsivity	☐$_{10}$ error detection/correction
☐$_4$ limited self awareness		

Sensory impairment:	☐$_1$ vision	☐$_2$ hearing	☐$_3$ touch/temperature
Motor impairment:	☐$_1$ difficulty ambulating	☐$_4$ right hemiplegia	
	☐$_2$ reduced hand/finger use	☐$_5$ left hemiplegia	
	☐$_3$ movement/coordination		
Emotional issues:	☐$_1$ restlessness	☐$_2$ anger	☐$_3$ sadness
	☐$_4$ loneliness	☐$_5$ reduced self esteem	
	☐$_6$ fear	☐$_7$ anxiety	

Figure 2. Impairments

Each impairment can come in combination with others, and each has its own range of severity.

2.1 The Three Month Window

A well established phenomena in the field of assistive technology is system abandonment. Studies suggest that the ability to match individual needs to the selection and development of devices is critical, and that assessment practices for assistive technology must extensively involve the individual consumer [Bryant&Bryant, 1998; Reimer-Reiss, 1999; Scherer, 2002]. Our experience with is that most assistive devices are gathering dust in the closet within 3 months. We hypothesize that those who build and deliver assistive devices must consider the composite system aspect of the user, as well as the user's individual requirements. To do so will require AT manufacturers to come to grips with three difficult issues: (1) how to ascertain the requirements of all the components in the solution system, (2) how to scale the construction of custom solutions once this information is known, and (3) how to integrate the solutions with existing components (human, hardware, software) that can sustain a solution over months and years. We discuss concrete answers to 1 and more speculative answers to 2 and 3 in this paper.

3. Preliminary work

Sohlberg's work focuses on developing and evaluating compensatory cognitive systems for persons with brain injury. In recent years, her laboratory and university clinical practice has noted the increased interest on the part of clients to explore using electronic devices such as prosthetic memory aids (Sohlberg&Mateer, 2001). More systematic study of the barriers and needs of persons using electronic devices requires the development of monitoring devices and an understanding of computer technology on the part of rehabilitation researchers. In the spring of 2000, the mutual interests of Sohlberg and Fickas led to the formation of a graduate seminar at the University of Oregon for students in Computer Science with the help of several persons with brain injury and their caregivers. The topic was the use of technology to overcome social isolation suffered by people with cognitive impairments. The students in the course worked to develop a web enabled system that supported e-mail interaction. The prototypes that came out of the seminar provided enough of a proof of concept to encourage further exploration.

The seminar results encouraged the authors to run a more formal, follow-up study during summer 2000. This study focused on HCI issues in the population, and as a spin-off, the effectiveness of traditional UI usability experiments with the population. Eight survivor/caregiver pairs displaying different cognitive profiles were recruited to help evaluate the different e-mail interface conditions. All subjects indicated feeling socially isolated and desired more contact with family and friends. None were currently able to use a computer independently and had little or no experience with electronic mail. We can summarize the results as they pertain to this proposal as follows: There is high variability in the ability of those in the population to use traditional user interface designs. A one-size-fits-all approach that attempts to design the "cognitive-impaired interface" is not possible. The study further helped to refine methods to measure user e-mail skills and document user response to support. Specifically, we developed a qualitative evaluation process to log and analyze critical incidents observed by a multidisciplinary team of researchers in computer science, social science and cognitive rehabilitation while jointly watching participants compose and send e-mails. A summary of this work can be found in [Sohlberg et al, 2002a].

More recently, we conducted focus groups around the state of Oregon, in both rural and urban settings. We interviewed over 80 individuals and collected useful and previously undocumented information on potential email use by both TBI survivors and their caregivers. Some items of interest from our focus groups are given below.

When asked what they would like to use email for (or currently use email for), survivors noted the following:

- Stay in touch with people who might not call, but will e-mail.
- Keep up with daily events of extended family.
- Sharing jokes.
- Keep a lot of people up to date with what's happening.
- Receive support from wide network of friends and family.
- Social learning can take place without the level of repercussion in face-to-face situations. "You can get your hand slapped and it doesn't hurt so bad."
- Provides an opportunity to make new friends. "They may not be in the same city, but at least I have a friend". "People that I've met online are a hundred times more understanding than my own family has been."
- The relative anonymity of email. "When I find out people are just pacifying or placating me, it's an insult. And yet they don't do that when I'm emailing."
- Social isolation can be a problem, but in general "We don't want our life to be on the computer, but it may be a way of reaching out and stepping out, and being an open door."
- Safety feature for communicating with others. "You can read it and say, gosh that doesn't sound very nice, you read it, edit it, reread it."
- Communicate with legislators - self advocacy.

When asked why email might be different than the phone, individuals answered as follows:

- Faster than mail.
- More frequent than mail/phone.
- Don't need to deal with answering machine.
- After phone call, can't remember content of conversation.
- People can write things they would be uncomfortable saying.
- Easier to follow written conversation (less time pressure).
- Gives time to think about what to say. (Same comment given by those who had tried to use IM chat.)
- Can email when they have time; less intrusive.
- Can be very brief; less time commitment than call or conversation.
- Less intrusive & distracting than phone.
- Easier to communicate by email with people you don't know well, who don't understand TBI.

Harder to quantify, but consistent throughout focus group sessions and lab studies, was a general enthusiasm by survivors for a prospect of gaining access to email. The current feeling is one of resignation that they will not be able to use a computer, let alone email – it is typical that TBI survivors have more than one computer gathering dust in a corner or closet. In the focus groups we met with, participants expressed unqualified excitement at the prospect of being able to perform an activity previously thought to be inaccessible to them.

4. A Personal RE Process

The primary result reported in this paper is the definition of a personal RE process we call CORE. We will discuss CORE in detail in this section. We also have some preliminary work in the area of system delivery and runtime monitoring. These two topics will be discussed in later sections.

CORE (**C**omprehensive **O**verview of **R**equisite **E**mail skills), allows us to evaluate a TBI survivor *and* his or her ecology/environment to gain the knowledge necessary to deliver an email solution as a composite system. A critical feature of CORE is the emphasis on functional assessment rather than exclusive use of standardized, norm-referenced tools to determine the potential for success using an AT/AAC system (Assistive Technology, Augmentative and Alternative Communication). Functional assessment concentrates on the client's performance during everyday tasks, particularly those tasks most relevant to the client and his/her use of the AT/AAC system. Unlike standardized testing, which requires strict adherence to task instructions, the examiners are free to modify their input to the individual (e.g., repeat instructions; increase prompting) in order to determine the conditions necessary for optimal performance.

At present, CORE is an examiner-based process. Contrast this with an automated process that attempts to remove a human examiner from the loop. This is neither feasible nor desirable with the TBI population. In particular, much of the challenge is to find a means of putting CORE in the hands of professionals who work with survivors and their family and careproviders on a day-to-day basis. This said, we retain a goal of automating the components of CORE that make sense. The CORE process consists of the following elements.

1. *Computer User Profile*. Provides background information on the client's injury, cognitive-linguistic symptoms, social communication and computer use.
2. *E-Mail Task Assessment*. Provides a functional assessment of the client's strengths and impairments by observing performance on a variety of email tasks under different conditions.
3. *Environmental and Capabilities Self-Assessment*. Identifies access and opportunity barriers and resources from the perspectives of the client and caregiver.
4. *User Requirements*. Elicits the goals and expectations of the user in terms of email.
5. *Observation of Natural Communication and Activity Patterns and Physical Environment*. Provides information on the client's communication and social activity as observed at home and in the community.
6. *Technology Fit Summary*. Filled out by the examiner, this provides information on the types of issues that are expected to arise when attempting to install an email system in the client's living space.
7. *Training plan*. Identifies areas where the user has the potential to be trained to overcome current problems, thus obviating the need for scaffolding built into the email client.

The CORE process is currently a mixture of handbook material (e.g., forms and instructions for conducting an assessment session) and software for performing laboratory assessment of a client's skills [Sohlberg et al, 2000b]. In summary, CORE is focused on providing a highly individualized view of a client's goals, corresponding skills, and overarching environment. In the next section, we will describe our initial evaluation of CORE on a TBI survivor.

5. Michael: A Case Study

We have recently completed the CORE evaluation process with two TBI survivors. We report our results for one of those survivors here. For privacy reasons, we use fictitious names and limit reporting specific details of each survivor's life. Michael is one participant in a longitudinal study we are conducting over a five year period. We recently completed Michael's CORE assessment and are now in the process of developing his training plan, technology fit summary, and construction and delivery of his email client and hardware. (We have also developed a low cost, Linux-based box and modified OS interface for Michael to use.) While our results are at the first stage of a multi-stage project, we believe they summarize well (1) the past two years of studying the TBI domain and the email application, and (2) the need for a personal RE process exemplified by CORE. Deciding whether CORE is at its finished stage will require concentrated analysis of Michael's goals and expectations, and the composite system that surrounds him, over the next 1 to 2 years. Our goals in this paper are twofold. First, to provide an entry for those interested in working on a personal requirements engineering process, and specifically for those interested in system building for a population unable to use mass-market, internet-based, communication software. Second, our hope is that a personal RE process like CORE will foster research on other mass-market computer tools that can be brought down to the personal level, and hence, made more usable by under-served populations.

5.1 Michael's background

Through use of CORE, we gathered the following information. Michael had a brain tumor in mid-life and subsequent surgery fifteen years ago. He was a teacher for many years and did not work after his brain surgery. He lives alone with occasional support from friends. He has school age children, although he and his wife are divorced.

He has approximately five people with whom he would like to correspond via email. He has two computers that he has never turned on – he cannot figure out how to use them.

5.2 Michael's email skill assessment

A central piece of the CORE process is an online email skills assessment. This is held in an office setting, and can have from 1 to 3 professionals involved. For research purposes, we chose to use: an examiner trained in cognitive rehabilitation, a note taker trained in qualitative methods, and a computer science expert. Our goal is to eventually to generate enough documenting material to allow a single cognitive rehabilitation specialist to administer the assessment. The assessment consists of a computer tool for generating mock email GUIs in context. Currently, all GUIs are built in advance and the tool allows the examiner to sequence through them in arbitrary order. Each comes up in the context of a focused task, e.g., "read the email from your doctor and create and send a reply." The tasks are constructed to evaluate potential problems affecting email due to: physical impairment (motoric, visuoperceptual), language impairment (auditory comprehension, reading, writing), cognitive impairment (attention/memory, executive functions, procedural learning), response to help modes (graphic prompts, speech prompts, text prompts), computer skills (mouse movement, button-click, keyboard use), and task conceptualization (ability to understand and stay on task). There are three key outcomes from the assessment: (1) A training plan that will target certain skills through what we call direct instruction and meta- cognitive strategy training. It is hypothesized that the application of these two instructional/rehabilitation models will permit individuals with amnesia and executive function impairments to learn a functional multi-step task such as reading, composing, and sending e-mail. (2) Parameter settings for the email client delivered to the user, settings that reflect data obtained in each of the areas assessed. (3) A set of monitoring specifications for runtime analysis of a user's goals. A *partial* summary of Michael's assessment is given below, along with ties to training, assistance, and monitoring.

Motoric

- *Assessment*: hunt-and-peck, slow release of keys.
- *Training*: standard keyboarding skills.
- *Email tailoring*: set key sensitivity to low.
- *Monitoring*: focus on multi-key patterns. Readjust key sensitivity to reflect typing skills.

Language

- *Assessment*: reading comprehension adequate for short paragraphs. Writing is telegraphic and very slow (see Motoric).
- *Training*: none.
- *Email tailoring*: offer form-based replies that minimize typing.
- *Monitoring*: Track use of forms supplied. Track change in length of replies (either improvement or declination).

Cognition

- *Assessment*: Moderate difficulty with the following: (a) alternating attention between elements on screen, (b) holding on to task instructions, (c) written replies did not correspond to requested information in sender's email. Uses trial-and-error strategy when stuck. Lack of procedural learning across trials.
- *Training*: Replace trial-and-error strategy with meta-cognitive strategy (e.g., teach to read email twice, write response and recheck that it corresponds to senders).
- *Email tailoring*: Include a to-do list recipe/prompt for replying to email.
- *Monitoring*: Track latency between known steps in replying. Gather feedback from email partners on coherence of Michael's email replies (manually through field notes or automatically through computer generated questionnaires).

5.3 Michael's Home Environment (Ecology)

Michael lives in his own house. A home visit was arranged for two field researchers on the project. Many minor problems were found (e.g., no clear space to place box, access to phone is partially blocked, general mess and disorganization). Michael was given a set of tasks to prepare for the delivery of the computer. Placement and access to computer remains a question (e.g., Will Michael remember that the computer is there? Will it eventually become buried under junk? Will floor access become restricted with accumulating junk?). The first three months will be critical in solving these issues.

5.4 Michael's Expectations and Goals

The importance of doing a personal RE process is evident with Michael. While he does share some of the goals and expectations seen in focus group meetings (see section 2), his primary goals were not captured, and we argue, could not be captured by a general TBI set of requirements taken from a broad study. We reproduce the results of Michael's goal identification session in the table below. Two things were striking to us. First, Michael's top goal is not to become more social, but to pick up a new skill. He is intellectually curious and email is a new challenge. His most favorable outcome is to reduce any dependency on online assistance. Hence, a goal of the system we deliver should be to remove assistance whenever feasible (e.g., monitor for continuing need of assistance and adapt the system to remove it when possible). On the downside, it appears from other parts of CORE results that Michael will never be able to fully use a raw email client. However, his goal can be translated into an aggressive monitoring and adaptation strategy that removes assistance when it makes sense.

Michael's second goal is also worth noting. It became clear during the interview that Michael was not looking for email chit chat opportunities. He wanted to carry on meaningful discussion. It seemed somewhat less important *who* his partners were than the *content* of the discussion they could provide. Our take away message from this goal is that Michael's email partners must be made aware of his interest in exchanging ideas on topics of interest to Michael. On the downside, this will be a tremendous challenge to the type of support we can give Michael in carrying on such discussions. His email assessment showed that he is currently unable to reply in a coherent fashion to even simple email such as an inquiry from his doctor saying "Which time would work best for you for your next visit, Tuesday at 4PM or Thursday at 4PM?" Michael's response was "Thank you very much." We hypothesize that formed-based email might help. The general idea is to have packaged messages with fill-in-the-blank opportunities. We have done lab studies with this style of email and it works moderately well in the constrained sessions we have run [Sohlberg et al, 2000a]. Whether it can be made to work with Michael is an open question. We will build some form-based components into Michael's email client as optional conveniences. We will monitor their usage, as well as some quantitative data on his replies. We will also add a training piece that teaches Michael reading and responding skills that can mitigate his current problems with impulsiveness.

Michael's third goal is encouraging. He recognizes that he can have problems recognizing social cues and conventions, and he related several stories of these problems taken from recent experience in face-to-face settings. It is possible to build some out-going filtering into the email system we deliver. Such filtering can be seen on popular mass-market email clients, e.g., giving the user an "aggressiveness rating" on outgoing email based on use of certain hot words in the reply. While we may consider such filtering in the future, our initial approach will be to view it as a composite system problem: the solution is not to be found in "fixing" one component of a larger system, but instead to build a monitor for each email partner to ascertain their level of satisfaction or discomfort with Michael's replies. This specializes the problem to email dyads. We suspect that some of Michael's partners will be relatively immune to certain language or responses, while others will take offense. There is nothing particularly fancy about the monitoring. Our monitoring tool will periodically give the partners a questionnaire that allows them to rate the communication they have been having with Michael. (This questionnaire is drawn from our pilot study of both survivors and their careproviders feedback on email exchanges [Sohlberg et al, 2000a].) The results will be passed to members of our research team. Of course, in the future we might foresee a direct link between partner results and adaptation of Michael's client, making the human's role one of overseer. For instance, if one partner is put off by Michael's use of strong language, we might attempt to automatically install an out-going filter for email destined to that partner. But this is in the future, at a time when we know more about the proper responses to problems in the system. At this point, we are interested in implementing the monitoring hooks necessary to gather the feedback.

Goal #1: **"I want to improve my ability to learn a new skill, specifically e-mail."**
Most favorable outcome thought likely: **"proof of e-mailing independently; no help required"**
More than expected success: **"When stuck, I could be helped via phone contact (with support staff)."**
Expected level of success: **"I want to learn how to e-mail. I may occasionally get stuck and need help (i.e., someone comes to my home to show me what to do)."**
Less than expected success: **"I will need lots of help."**
Most unfavorable outcome thought likely: **"I can't learn e-mail. You have to tell me how to do it."**

Goal #2: **"I want to feel more connected with my e-mail partners, particularly [my family]."**
Most favorable outcome thought likely: **"I want to feel like I'm sharing authentic/interesting information with everyone, especially [my family]." "Not just talking about the weather."**
More than expected success: **"Sharing interesting content with at least one friend and one family member."**
Expected level of success: **"Sharing interesting content with at least one person."**
Less than expected success: **"E-mails will be mostly superficial."**
Most unfavorable outcome thought likely: **"Responses to e-mails will be negative. They will hate what I say."**
Goal #3: **"I want to decrease my impulsivity and increase my social judgment, and organization."**
Most favorable outcome thought likely: **"Very few instances of impulsivity & lapses in social judgment; less than 1 per week."**
More than expected success: "**Instances of impulsivity & lapses in social judgment decrease to no more than 1-2 instances per week."**
Expected level of success: **"Instances of impulsivity & lapses in social judgment decrease to no more than 2-3 instances per week."**
Less than expected success: **"Barely noticeable change; 4-6 instances per week."**
Most unfavorable outcome thought likely: "**No change."**

5.5 Summary of Michael's CORE results

By using a personal RE process with Michael, we were able to learn critical information that must be factored in to any system delivered to support him in email use. First, we obtained a snapshot of his current strengths and weaknesses in terms of email skills. Second, we gained information on his personal environment. Third, we got a snapshot of his current social circle. Fourth, we acquired his requirements (goals and expectations) in introducing email into his life. We cannot say that paying attention to each of these guarantees success. But we can confidently argue that if we did not pay attention to each, and delivered a generic system, there are too many paths to failure. What can we do to close off even more of those paths? Perhaps first and foremost, we can train Michael to improve some of his email skills. Success here is twofold: (1) training can allow us to remove scaffolding from Michael's client, meeting one of his top three goals, and (2) we hypothesize that training in email skills can transfer to other social situations. Clearly the latter is speculation until we can again interview Michael and his social circle after email has been in place for some time. But we remain confident that transfer can take place. More specifically, we have begun to study the feasibility of introducing synchronous communication (e.g., instant messaging) once a user has mastered email.

The second way we can enable success is to remove the potential for failure. Our approach here is to build an email client that is tailored to Michael's skills, and avoids putting him in situations where his weaknesses come into play. If he becomes easily frustrated with typing, and cannot be trained to be a better typist, then minimize typing. Currently we are exploring fill-in-the-blank style messages, although a word-completion type of assistant might also help. Of course, at some point it is impossible to remove barriers and still retain the ability to email. In these cases, we provide standard assistance (e.g., a to-do list or recipe for composing a reply). The key is training: once we determine the type of assistance we will need, we add training on that assistance, itself. For instance, procedures for remembering to use the to-do list when stuck.

Third, we can view the initial CORE results as just that, initial. There is only a limited amount of data that can be gathered in an office setting. The initial results can set up hypotheses about what type of system will work, and can raise potential warning flags. Monitoring is necessary to assess their validity. Clearly, monitoring is a tricky issue here. Gathering *quantitative* data is straightforward (e.g., number of emails sent, length of emails, occurrences when help was needed). However, we also need qualitative data (e.g., Are Michael's goals and expectations being met? Are his email partners satisfied with their interaction with him?). Instead of trying to take a high-tech approach to the problem by building sophisticated inferencing mechanisms and NLP parsers, we have chosen a more direct approach: ask the humans involved for feedback. This shifts the problem from one of AI to one of HCI: can we find a means of collecting qualitative data that is (1) automated, and (2) likely to be effective and used by the humans in the system? Clearly there are negative examples of such data collection, the proliferating set of web pop-up survey boxes being one. The question we wish to explore is if very specific and in-situ questions can be effective. We are building such questionnaires into Michael's system, but will not have results to report until further in the longitudinal study.

6. Building a Custom System

While our goal is to make the construction of tailored email systems an automated process, we currently include manual steps. Using our data over the last two years of lab studies, we have constructed a parameterized email client that can be specified with a simple XML-based file. We can turn on and off features, set numerical values, and do rudimentary descriptions of business rules (e.g., the policy of what to do with old email). Some example parameters include text size, component (e.g., button) size and placement, mouse or mouse-less operation, speech output (or not), max message size of inbox, email filtering rules, to-do list assistance, form-based replies, spell checking, word prediction. What we have yet to do is to tie the CORE process to system construction in an automated fashion. Our current method is for members of our research group to meet to interpret the results of CORE and map those results to actual system specifications. We realize that if this step cannot be automated, it presents a scale challenge: we cannot expect a large set of survivors to have a research team available to translate CORE results to a delivered system. However, at this point in our research, we expect that the translation process will remain only semi-automated. Our priority is getting systems into the field and gathering data on our set of case study participants.

7. Monitoring

While our goal is to automatically generate the monitoring specifications for a delivered system, we currently hand-generate the monitoring specifications from CORE results. Once these specifications are written, we do have a monitoring tool, called Emu (www.emu-project.org) that can enact the monitoring of the running system. As an example drawn from an earlier user, who we will call Patricia, we determined that Patricia had the following goal:

"I would like to email and ask my friends for a ride sometimes."

Using a simplified version of the goal refinement suggested by KAOS [Dardenne et al, 1993], we can refine the goal/requirement into the following tree:

```
Ask friend for a ride
            ⇒ Generate a request
            ⇒ Send to friend
            ⇒ Have friend reply in time
            ⇒ Read reply in time to meet transportation need
```

We have described in a separate paper how we use formal tools to move from this characterization of the goal first to a Linear Time Logic specification, then to a Buchi Automaton, and finally to an Emu specification [Fickas et al, 2002]. Here we will briefly describe the final portion, the Emu specification. As context, Emu (Event Monitoring Utility) has the following features:

1. Emu is an internet service. It connects, on a socket level, with clients. (We have also developed a web front end that accepts SOAP messages.)
2. Emu allows requirements to be installed, e.g., the ask-a-friend-for-a-ride requirement. Installation can be on a just-in-time and ad hoc basis, or a template can be installed and stored in the Emu library prior to use. These templates can be given triggering conditions that invoke the requirement, i.e., put it into place with context information, set timings, and begin monitoring.
3. Emu receives events from clients through a distributed listener architecture, and delivers events to gauges and other interested components. This borrows from earlier work on requirements monitoring [Fickas&Feather, 1995].

The general organization of the tool is such that events are sent from clients to Emu. This model is like a distributed event listener pattern. Emu listens for trigger events from the client. When Emu receives such a trigger event, a monitoring tree is initialized and context information is taken out of the triggering event and put into the tree. Context information can indicate the involved clients, the module that generated the event or the recipient of a message. The specification of an event tree takes the form of an XML document. Emu reads the XML specification and creates an internal representation of the event tree that it uses for monitoring clients. When the trigger event occurs it means Emu should begin monitoring the rest of the events in the tree. Figure 3 shows a portion of the XML spec for the ride request goal.

Once we are able to monitor the progress of a requirement, we can begin to contemplate ways to use the monitoring information. One idea that grows out of monitoring is a runtime gauge that shows the status of a requirement. Figure 4 shows a simple gauge that we have developed that uses the tree itself as its visualization metaphor. The left panel shows the fault tree's structure while the right panel lists information on the selected Reply Event. Green (light grey in black and white) leaves represent events that have occurred while red leaves (dark grey) represent events that we are waiting to occur. The gauge is driven by signing up as an Emu listener: it tells Emu that it wants to know the status of the tree as it evolves. Emu sends its own status information out to the gauge. The final step taken to complete the project was to install a "requirements invoker" onto the email client of Patricia. This is shown in figure 5 where Patricia now has a pull-down menu item that will invoke the requirement (and trigger Emu to start monitoring). It is interesting to note that the other survivors in the focus group (of about 5 total) did not endorse this requirement: only Patricia made it a goal.

Patricia's ride example reiterates our current philosophy on monitoring: instead of giving Patricia a general interface and then attempting to infer when she is asking for a ride, we instead built her ride goal directly into the interface. This allows us to trigger monitoring unambiguously. It also simplifies Patricia's task by placing her goal explicitly in the interface.

8. Related Work

The CORE was developed based on assessment models used in the fields of assistive technology (AT) and augmentative and alternative communication (AAC). The Assistive Technology Outcomes Measurement (ATOM) model [Weiss-Lambrou, 2002] emphasizes matching the person and technology [Scherer, 199] within the context of the World Health Organization International Classification system of disablement (i.e., integration of impairment, activity, participation, and environment/context assessment) [WHO, 2001]. The Participation Model [Beukelman&Mirenda, 1998], used in the related field of AAC, emphasizes a comparison of the functional participant requirements of non-disabled peers of the same chronological age as the AAC user. This model also includes an assessment of "opportunity" and "access" barriers for communication.

Singh provides a comprehensive discussion of access barriers due to language limitations in elderly and non-disabled adult users on the analysis of hypertext on the Internet [Singh, 2000]. The paper also explores options for providing visual, cognitive, and linguistic aids through sophisticated interface design. What is not discussed is how to evaluate and monitor individual user needs, match the needs to interface design options, and monitor user satisfaction.

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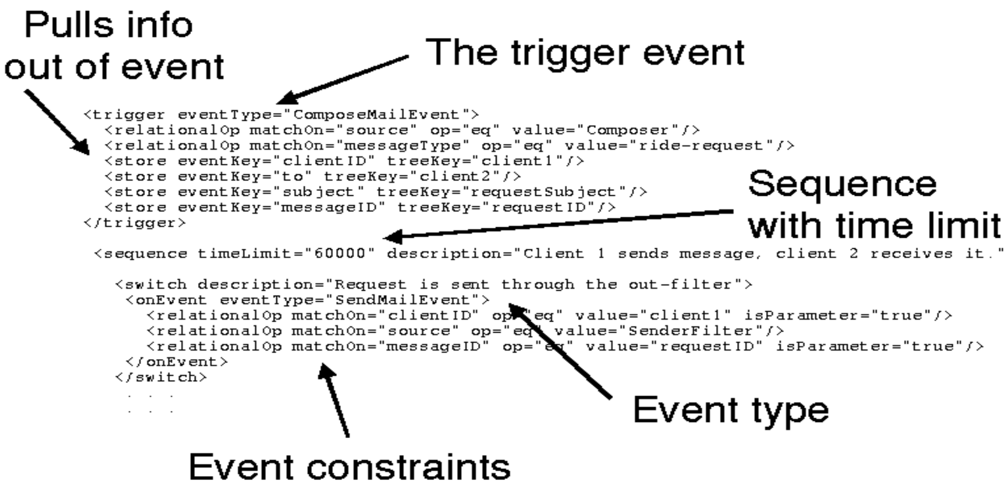

Figure 3. XML spec of ride request goal

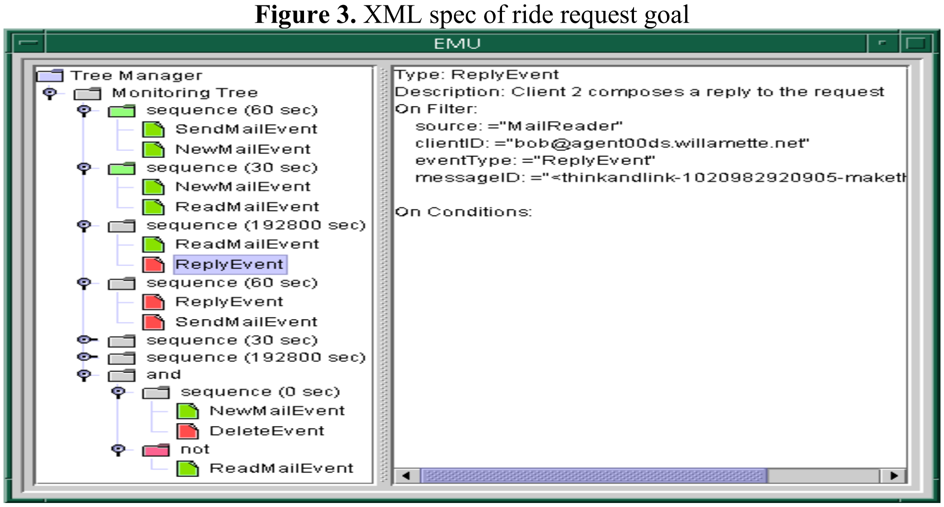

Figure 4. A gauge monitoring the ride request scenario.

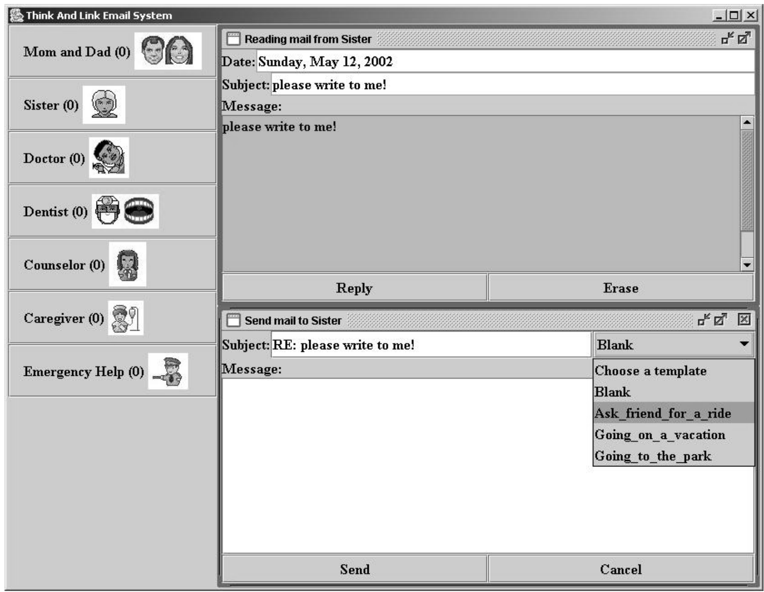

Figure 5. An added menu choice