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Development of a Model of a Stroke Care Process

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ABSTRACT

Aim. The paper presents the development and structure of a generic stroke care simulation model, used in designing of a stroke unit in Sweden.

Background and rationale. Designing new health care spaces is a multifaceted process; requiring multi-professional (nurses, other healthcare professionals, building planners and architects) involvement. To secure that the patients' interest are in focus the different stakeholders need to analyze and develop a common understanding of the care processes that are to take place in the new space. Modeling and simulation is one significant method, making it possible to depict the dynamic structure of the system and experiment with the model, asking "what – ifs" questions.

Methods. System dynamics, a modeling method was used to develop the model. The iterative and group-modeling process included development of a quantified model (with a multi-professional design team, based on evidence from the literature, and a survey from stroke care experts), and validation of the model.

Results. The dynamic care model developed included variables that are essential in modern care, such as patient-participation, care-planning, and teamwork.

Conclusion. The presented generic model provides a framework for exploring, comprehending, and communicating complex ideas about stroke care.

Key words: Nursing models, policy, simulation models, stroke care, designing of new spaces

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Introduction

The present paper reports the development of a generic simulation model used for planning a stroke care unit. Reasons for using a model were to enhance the potential for communication and to develop a greater understanding of the stroke care process for participants in a multi-professional design team (nurses, physicians, and physiotherapist, architects, and building planners), prior to decisions of the design solutions. The modeling process brought together evidence about stroke care, synthesized and compromised the knowledge and concept to a visible model that acted as a communication medium in a multi-professional design group. We present here the process of developing the simulation model, the structure of the model and the underpinning evidences from the literature and from a survey from stroke care experts.

Simulation is a mediated technology of growing interest for nursing. The technology makes it possible to experiment with models of complex realities. It offers the potential to describe processes in a dynamic way and is suitable for exploring, comprehending, and communicating complex ideas about care processes (Sterman, 2000).

Background and context

Designing new health care spaces is a complex task, requiring multi-professional involvement. In order to secure that the patients' interest are in focus the different stakeholders need to analyze and develop a common understanding of the care processes that are to take place in the new space. Recently, major changes are taking place in the design process of new health care spaces. Briefing, the process of identifying and articulating user's requirements and needs at the very early stages of the process, is in focus (Ryd, 2004; Ryd & Fristedt, 2007; Smith et al., 2003). What is strived for is a process that considers the activities within the organization as a first essential step, rather than concentrating on construction issues (Barrett & Baldery, 2003; Kamara & Anumba, 2001; Kelly & Hunter, 2005: Yu et al., 2007). The initial stage of the design process in health care should specifically

attend to the goals of the care and the care processes that are to take place in the envisaged building (Gesler, et al., 2004,;Ulrich & Zimring, 2004). In addition, a recent trend in health care design strongly advocates the use of evidence- based design (EBD) (Stankos & Schwartz, 2007; Ulrich & Zimring, 2004; Vischer 2008).

Challenges of designing stroke care units

Stroke is a major cause of death, threatened and reduced health, and a patient's dependence on support after the acute phase (Brainin et al., 2004). The increase in knowledge of neurological recovery after a stroke has led to new treatment strategies, where the importance of the physical environment and rehabilitation is on par with the importance of the medical treatment (Johansson, 2000;Keysor et al., 2006;Nudo et al., 1996). It is crucial that the various dimensions of health are considered and that the whole stroke team is involved in assessing, planning, and evaluating the care provided (Langhorne & Dennis, 2004).

Several studies have demonstrated that patients with an acute stroke benefit from care at a unit that is geared specifically to stroke patients (Donnan et al., 2008; Langhorne & Dennis, 2004). At stroke units, the specialized care results in lower mortality, more patients who become independent in activities related to daily living, and more patients who can be discharged to their homes (Donnan et al., 2008; Langhorne & Dennis, 2004; Stroke Unit Trialists' Collaboration, 2007). Several components (in combination) are suggested to have an impact on a patient's recovery and health such as observation and assessment of the individual patient's treatment needs, early treatment intervention, mobilization and the prevention of complications, such as pressure ulcers and dehydration, ongoing rehabilitation planning and evaluation of the care provided (care planning), inter-professional teamwork, and a high number of professionals with special expertise and knowledge in stroke care. These components are all helpful as a first step in considering the care planning for stroke patients and investments in improved clinical effectiveness or design layout.

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Aims

System dynamics modeling was used in a design process for a new stroke unit, to analyze essential factors in stroke care and their mutual influences and the impact on a patient's health. The specific aims were to:

- Identify important key factors that have an impact on a patient's health in stroke care and highlight the complex relationship between the structural, process, and outcome factors involved, in order to achieve optimal stroke care.
- Construct a useful generic simulation model, in order to be able to study the dynamic relationship between factors that influence the course of events in a patient's state of health.

Development of the Model

System dynamics

System dynamics has a holistic and interconnected "world view" (Sterman, 2000). The philosophy of the method is that the performance of a complex, dynamic system depends on its intrinsic structure, that is, the way the different variables interact and influence each other within the system, resulting in dynamic behavior (Sterman, 2000). Models of reality (a system) are created, with the aim of explicitly forging an understanding of how the structure generates behavior (output) over time within the system. The method reveals nonlinear behavior where stimulus and response are unequal. A small change may cause a greatly amplified response. With a developed quantitative simulation model, it is possible to manipulate the variables within the model and ask "what–if" questions. The method can be used to estimate the impact of variables even when full information is not available. Causal feedback loop diagrams (CLD), in which the feedback relationships are

portrayed, thus representing the influence between variables in the system, are used to conceptualize the structure of the system (Sterman, 2000). Arrows with a plus (+) imply that a change in the independent variable produces changes in the same direction in the dependent variable. Arrows with a minus (-) indicate that a change in the independent variable results in a change in the opposite direction in the dependent variable. The CLD can be transferred to a quantified model, which can be used to run scenarios and ask "what-if" questions. An example of a CLD is shown in Figure 1.

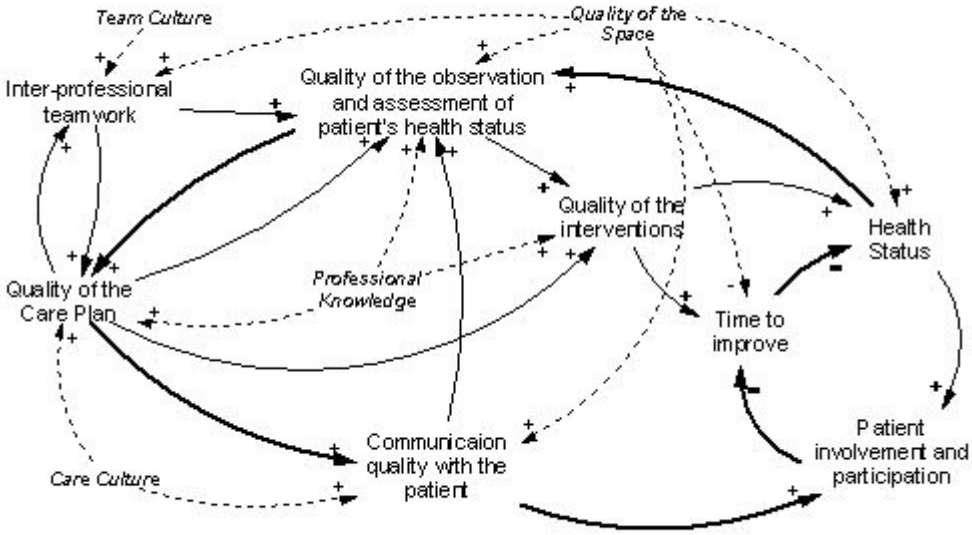

Figure 1. A Causal Loop Diagram of a stroke care process

System dynamics have been used in healthcare, foremost to analyze bottlenecks, waiting times and recourse? allocations (González-Busto & García, 1999;Homer et al., 2007; Wolstenholme et al., 2007; Wolstenholme, 1999).

The Model

The process of developing the model involved a series of iterative and systematic steps, which are presented in Figure 2. The modeling process was workshop driven (six workshops of 2-3 hours each) and took place over a period of approximately one year (Elf et al., 2007). The design team consisted of nurses, a physiotherapist, building planners, managers of the stroke unit, and architects was involved in the CLD modeling but not in determining the mathematical relationships. The group-modeling process is described in detail elsewhere (Elf et al., 2007).

Identifying important concepts central for the care process under study was an important first step. Key concepts were listed with the help of Donabedian's (1988) model, which stresses that quality in health care should be assessed from a patient's point of view and includes three dimensions: structure, process, and outcome. Structural factors are, for instance, the physical space, regulations, and cultural aspects that are of importance to health care. Process factors cover the care process, which means the human activities that are performed, and outcome factors represent the measured results of care intervention. This framework was acting as a basis for system thinking by asking questions such as what goals do we have for stroke care? What activities must be taken to achieve the goals? What factors in the context (space, cultural) do we need to achieve the goals?

The second step involved the exploration of concepts, using a critical dialogue within the design group. The concepts were discussed to unpack each concept. The literature was reviewed thoroughly to ensure shared clarity of the meaning of each concept and to apply an evidence-based

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approach to care. The CLD model developed slowly and each relationship was discussed in detail.

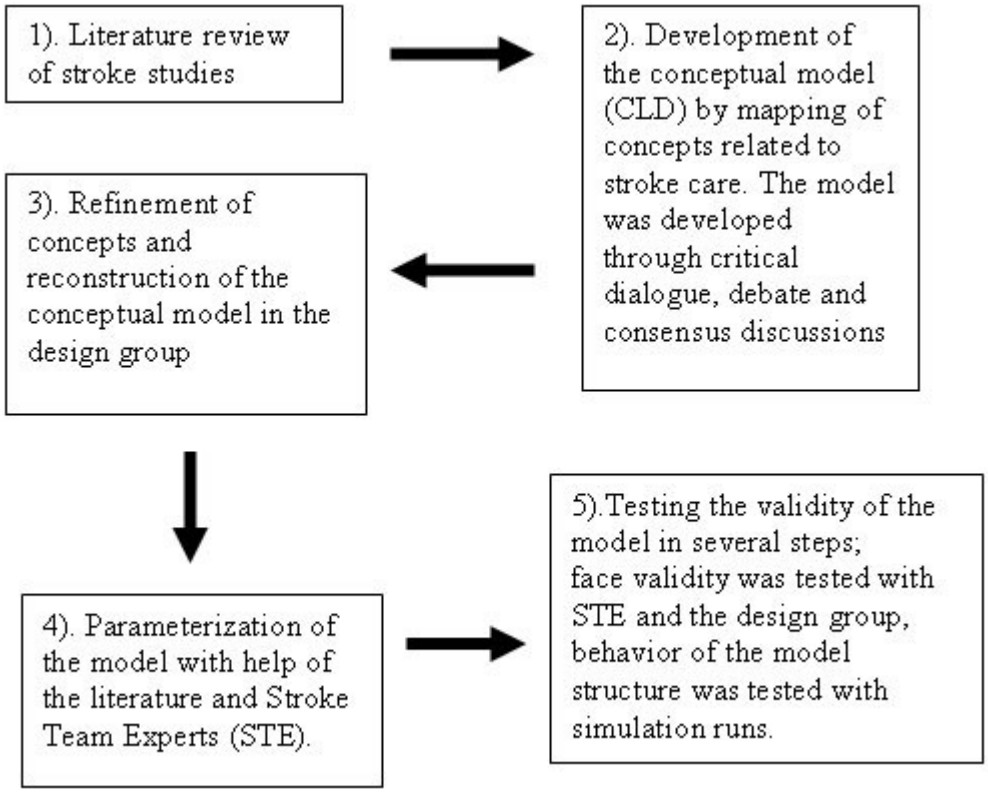

Figure 2. The model development steps

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Key variables involved in the model

The key variables included in the model are presented below, followed by a summarized description of the CLD in Figure 1.

Health status

In the model, health is defined as a medical and functional state. Health is an outcome of the interaction between patient functional status (i.e., implications of the medical diagnosis for a patient's potential to function as a human being in the society) and contextual factors, such as the design of the environment (WHO, 2001). The focus is not on the medical diagnosis, but on the person's level of health and functioning in the society.

Care planning

A care plan is a written document for those team members who meet the patient throughout the care period and used to assist in monitoring their contact with the patient. In that sense, essential information is available for relevant professionals who are responsible for patient care (Carpenito, 1997; Lindgren et al., 1992). A care plan—an essential process in modern health care—should illustrate the decision-making in patient care. This process involves assessment (diagnosis) of a patient's health and decisions about care interventions (management of care) (Ehrenberg, 2001; NANDA, 1999). The intervention selected in agreement with the patient should be documented in the care plan for each patient.

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Studies have shown that records often lack a structured care plan based on patient needs and that the notes are seldom based on clinical guidelines or evidence-based recommendations about care (Ehrenberg, 2001; Idvall & Ehrenberg, 2002). This is likely to have a negative effect on the quality and effectiveness of care (Ehrenberg & Ehnfors, 1999). It will also impede the co-ordination and continuity of care for the patients, two factors important in sustaining the expanded complexity of health care (Bjorvell et al., 2003; Krogstad et al., 2002). An explicit care plan is an important step in securing the patients' involvement in his or her own care. Unarticulated care actions are impossible to share and consequently give no influence and power to the patient (Ljungberg et al., 2001; Towle & Godolphin, 1999). Research shows that care planning is a purely professional task and decisions about care are made without any involvement by the patients or their relatives (Bjorvell et al., 2003). Effective care planning in stroke care is associated with stroke-specific assessment, documentation of care, and rehabilitation goals (Stroke Unit Trialists' Collaboration, 2007).

The team culture

In spite of a collaborative care organization, the quality of care may be threatened by insufficient teamwork (Atwal & Caldwell, 2002; Caldwell & Atwal, 2003). Involvement of several professionals in the care of stroke patients does not guarantee coordinated teamwork (Gibbon et al., 2002). Professional groups work side by side with the same patient, but may often have different aims, care plans, and recording systems. This may increase the gap between professionals, thus reducing the continuity and consistency of care for the patient (Pound et al., 1999). An integrated care plan has been reported as being one of the most essential facilitating factors in effective teamwork (White et al., 2000).

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The care culture

The culture determines prevailing values, beliefs, and assumptions about care. Clearly defined and shared goals of the professionals, which include underlying values and accountability, are important to effective and successful care (Kitson et al., 1998; McCormack et al., 1999; Rycroft-Malone et al., 2002). The adoption, for instance, of a patient-centered philosophy, in which shared decisions with the patient are emphasized, means that the health care organizations strive to facilitate the patient's participation in the care and rehabilitation process (Baumann et al., 1998; West, 2001; Wright & McCormack, 2001).

Professional knowledge

Professional knowledge has been suggested as a factor that has been shown to contribute to the significant differences between stroke units and general medical wards (Kalra & Langhorne, 2007; Langhorne & Legg, 2003; Smith et al., 2008). Study results show that skilled professionals make more precise observations and assessments of the patient's health problem. They know what to observe in relation to their professional accountability and how to use various instruments in order to make a more comprehensive and accurate assessment of the patient's health status (Stroke Unit Trialists' Collaboration, 2007; Donnan et al., 2008). The professional's knowledge has an impact on motivation for working with the stroke patient and thus on working morale (Baxter & Brumfitt, 2008; Brainin et al., 2004; Craig & Smith, 2007; Pound et al., 1999).

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The quality of the space

The quality of the physical space has a direct influence on the patient's health status (Ulrich & Zimring, 2004), and influences the opportunity for the professionals to make accurate observations and assessments of the patient's health status. Almost all assessment includes a physical examination and the professionals need to communicate sufficiently with the patient in private. It is thus necessary that the environment supports the assessment and communication process, in order to facilitate the care process (Ulrich & Zimring). Ulrich (1992) states that the health care environment should be supportive in order to facilitate coping with and reducing patient stress. A supportive environment fosters control over the immediate environment, over light and sound for example, but also control over information, knowledge and the environment to include the opportunity for privacy (Ulrich, 1991). In addition, the environment should promote social contacts and ideally provide access to nature and other distractions, such as art or literature (McCormack et al., 2004; Ulrich, 1992).

The importance of the environment to the stroke patient's scope for rehabilitation has been in focus recently. The World Health Organization's(WHO)) health model (international classification of functioning, disability, and health) includes the environment as one essential factor that influences the patient's health (WHO, 2001). Experimental studies show that an "enriched environment," characterized by access to stimuli and activity, influences recovery after brain lesions (Buchhold et al., 2007; Johansen-Berg et al., 2002; Johansson, 2003). Indredavik (1999) states that an important contributor to the superior outcomes in stroke units might be the "enriched environment," which is an environment that stimulates and challenges the stroke patient. Patients feel secure in such environments and the environment supports the patient in her/his rehabilitation beyond the physiotherapy hours (Pound, Sabin & Ebrahim, 1999). In a functioning unit, there is a motivated and encouraging attitude that supports the patient's own efforts to improve (Brainin et al., 2004). Studies

have also shown that patients are more satisfied with rehabilitation in their own home, where they experience security and autonomy (Wohlin-Wottrich et al., 2004; von Koch, Wohklin-Wottrich & Widén Holmqvist, 1998).

Observation and assessment

To make a correct and comprehensive assessment, the professionals need to make observations and use relevant instruments (Brainin et al., 2004; Langhorne & Pollock, 2002). The assessments of a stroke patient's health should include intellectual and cognitive capacity, emotional disturbance, and motivation and should cover the degree of motor weakness and sensory and visual loss (Langhorne & Pollock, 2002). Moreover, a patient's nutrition, skin, and activity status must be assessed and documented accurately (Brainin et al., 2004; Langhorne & Pollock, 2002). The progress of the patient's health status should also be evaluated and documented on a daily basis (Kaste et al., 2000; StrokeUnitTrialists', 2001).

Patient participation

The view of the patient role has been changed from that of being a passive consumer to that of an active participant (Ljungberg et al., 2001). Studies have revealed the benefits of involving the patients more fully in making decisions about their own care (Farrell, 1996; Langhorne & Legg, 2003; Ljungberg et al., 2001; McCormack, 2004;Wohlin- Wottrich et al., 2004). Stewart et al, 1999) demonstrated that effective care, professional–patient communication and improved health outcomes are interrelated. Communication is important in achieving consensus between the patient's and the professional's expectations, but also for patient participation in the decision-making process (Lewin et

al., 2001). Effective communication is linked to patient recall of, adherence to, and satisfaction with information (Lewin et al., 2001). Communication thus emerges as a factor that is crucial to patient-centered care (Lewin et al., 2001; Mead & Bower, 2000; Stewart et al., 1999).

Inter-professional teamwork

Contemporary stroke care strives towards a teamwork approach (medicine, nursing, physiotherapy, occupational therapy, speech and language therapy, and social work) in which the comprehensive health needs of patients are emphasized (Kalra & Langhorne, 2007; Langhorne et al., 2002; Stroke Unit Trialists' Collaboration, 1997; Stroke Unit Trialists' Collaboration, 2007;Wade & de Jong, 2000). It is clear that no single discipline has all the skills, resources and expertise required to manage all aspects of recovery from stroke. Several studies describe inter-professional teamwork as a key component in effective stroke care (Gibbon et al., 2002; Kalra & Langhorne, 2007; Kaste et al., 2000; Pound et al., 1999;Wade & de Jong, 2000). Each team member is responsible for her or his assessment, planning, intervention, and evaluation of the care (Langhorne & Pollock, 2002). However, the team should work in collaboration, including regular meetings to plan integrated care in agreement with the patient and relatives (Gibbon et al., 2002 ; Kaste et al., 2000).

Interpretation of the Model

In Figure 2, the CLD is presented, showing the main variables interacting in a stroke care process. Looking at the diagram (Figure 2), the patient's health status is a function of the quality of the care interventions the team provided to the patient which, in turn, are influenced by the quality of the observation and assessment performed by these professionals. According to the model, an increase in the quality of the observation and assessment will lead to an increase in the quality of delivered interventions, which will further enhance the patient's health. Improved health will increase

the potential to improve the quality of observation and assessment further.

The quality of patient care depends on the quality of the multitude of decisions that are made each day in clinical practice, which are likewise influenced by the observation and assessment of patient's health status performed by the professionals. The model indicates that an increase in the quality of the observation and assessment results in an increase in the quality of the care intervention and thereby influences the patient's health status. Moreover, there is a mutual influence between observation and assessment and the care plan. More accurate observation and assessment will improve the quality of the care plan and an adequately written care plan increases the quality of the observation and assessment.

A written care plan is also hypothesized to facilitate teamwork, in the sense that the discussions within the team will be more focused on the individual patient's health problem. It is also more likely that the various professionals' contributions will be more explicit and discussed more thoroughly. High-quality teamwork increases the quality of observation and assessment of the patient's health, since the collaborative analysis of the patient's health problem may contribute to a broader understanding of the problem and thus contributes to closer observation of nuances in the patient's health.

The model suggests that communication is an important factor in stroke care, both for the potential to make an accurate assessment of the patient's needs and health problems and also to bring about patient involvement and influence on her or his own care. If the quality of communication between the care professionals and the patient increases, the model hypothesizes that patient involvement will also increase. This will, in turn, have an influence on the patient's recovery time and consequently on the patient's health.

The care culture influences the quality of communication with the patient and relatives since a

strong care culture support factors that facilitate patient-centered care. Professional knowledge has been suggested as a factor that has been shown to contribute to the significant differences between stroke units and general medical wards. The model also indicates that the quality of the physical space directly influences the recovery time and thus, the patient's health status.

Quantification of the Model

In a first step, the magnitudes of each relationship were described with support of a thorough review of the literature. Next, Stroke Team Experts (STE) at different stroke units in Sweden were consulted (n=35) to give their view of the relationships in the model, with help of a questionnaire. The model was divided into a number of parts, each part dealing with one important variable in the model (e.g., communication quality). In each part of the model, a number of influencing variables were presented, describing a relationship between the dependent variable and certain independent variables. The relationship was described in a graph that established a one set relationship, such as the communication quality (dependent variable), as being influenced by four independent variables: the patient’s health status, the quality of the room, the care culture, and the quality of the care plan. For each important variable in the model, a data questionnaire form, which incorporated a set of graphs, was created. An example of a graph is presented in Figure 3.

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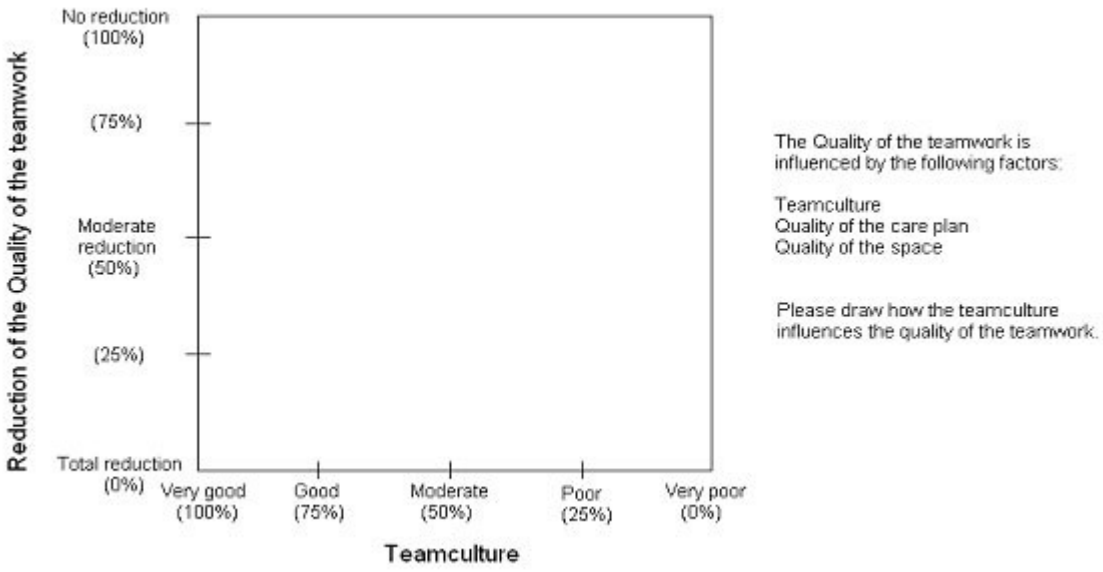

Figure 3. Example of a graph filled in by the STEs.

The focused relationships were presented in written text, for example, “the following variables influence the quality of communication: the patient's health status, the quality of the room, the care culture and the quality of the care plan. Describe how the communication quality is influenced by patient's health status”. The STEs were asked to set a cross on the graph at the best–best level. Then, the participants were asked how much they would consider the dependent variable to decline if the independent variable decreased. At each STE meeting, the project leader presented the conceptual model, followed by a description of how the graphs would be understood and completed. In addition, a document with the defined variables was distributed and the definitions were discussed in the group (Figure 4). The definitions were constructed with support from the

literature and were used as a support when the STE completed the graphs. The average values of the estimations of each graph were calculated and transferred into the simulation program, Powersim®.

Variables	Scale	Definition
HEALTH STATUS	**Very Good**	Patient is fully conscious and is able to manage activities in daily life (ADL) with no problem. No communication problem.
	Good	Patient is fully conscious but has functional problems and thus needs support with activities in daily life (ADL). Communicates understandably.
	Poor	Serious functional problems and needs help with activities in daily life (ADL) and movement. The patient finds it difficult to communicate.
	Very Poor	Unconscious and thus needs total help with ADL and movement.
QUALITY OF COMMUNICATION WITH CLIENT	**Very Good**	The team understands the importance of having good quality communication with the patient to ensure an optimal care plan. Communication is an important activity in the department's operational description. The team understands the importance of having good quality communication with the patient to ensure an optimal care plan.
	Good	The team understands the importance of having good quality communication with the patient to ensure an optimal care plan.
	Poor	There is mainly one-way information from the professionals. Some of the team understand the importance of good communication to ensure an optimal care plan and strive to achieve adequate communication.
	Very Poor	No communication, only one-way information from the professionals.

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Variables	Scale	Definition
QUALITY OF THE CARE PLAN	Very Good	The care plan includes contributions from each professional and their knowledge. The care plan is an active document and is used in communication with the patient, professionals and other units. The care plan is one document and is an obvious part of the patient's records.
	Good	The team meets regularly for care planning. There is an explicit care plan in which large parts of the care process can be followed. The care plan includes contributions from each responsible professional with his/her knowledge.
	Poor	Care planning occurs intermittently and is seldom written in the patient's records. The plan has a medical focus. The plan is not used actively and systematically in discussions with the patient, relatives, other professionals or units.
	Very Poor	No care planning exists in the patient's records and there are only retrospective notes regarding drug distribution.

Table 1. Examples of the definitions of the variables

Validity test of the model

The test of the model validity was performed in several iterative steps. First, a face validity of the structure of the model was obtained in the design team and in STE groups. Moreover, face validity was ensured by the group-modeling process, in which the model was developed, using evidence from the literature, as well as in collaboration with people working with stroke patients (the design group). The model was also discussed with STEs, who confirmed the structure of the model. The STEs supported the quantification of the model by describing the magnitude of the relationships

between the variables in the model. Finally, the model was used in the design group that developed and used the conceptual model in the planning of a new stroke unit. The group found the model accurate and useful in their work (Elf et al., 2007). In addition, the structure of the model generated a hypothesized recovery for a stroke patient under various conditions that were logical and in accordance with the literature.

For example, the group tested the health progress for a patient under very good conditions (professional knowledge) and respectively, under very poor conditions (Figure 4). Several validity tests of the model were performed, such as a structure-oriented behavior test such as extreme condition tests, and behavior sensitivity tests (Barlas, 1999).

"What if Scenarios"

1. **A very good health care context assuming:**
   - A patient with a major stroke but a good prognosis
   - The quality of the space is very good
   - The team culture is very good
   - The care culture is average
   - The professional knowledge is very good

2. **A unit characterised by a poor health care context assuming:**
   - A patient with a major stroke but a good prognosis
   - The quality of the space is very poor
   - The team culture is very good
   - The care culture is average
   - The professional knowledge is very good

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Figure 4. Patient's health progress simulated under various conditions

The Model used in design work of the stroke unit

The model was used in a design group to guide decision-making about the design of a new stroke unit, to facilitate communication of stroke care among various professionals, and to facilitate conceptualization and a shared view of a stroke care process. The design team exposed the main factors for a successful stroke care unit and analyzed the system in detail, supported by system dynamics. The team created various scenarios, using the model, in order to challenge beliefs and mental models of the practice and important factors influencing stroke care. Figure 5 shows some of the scenarios created in the design team.

"What if Scenarios"

1. A very good health care context assuming:

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- The team culture is very good

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- The care culture is average
- The professional knowledge is very good

2. A unit characterised by a poor health care context assuming:

- A patient with a major stroke but a good prognosis
- The quality of the space is very poor
- The team culture is very good
- The care culture is average
- The professional knowledge is very good

4. Scenario 1
5. Scenario 2

Figure 5. Examples of experimentation with the model

The design team found the model useful in understanding the stroke care process and supporting discussions in the group (hidden ref). The modeling project is described and evaluated elsewhere (Elf et al., 2007).

Implications for practice

Modeling and simulation can be an important tool for facilitating communication in multi-professional quality improvements work, in which the participants have their own language, knowledge and approaches. There is a need for many more studies using modeling and simulation. The present study can be used as an example how to use the method in healthcare research and practice. In addition, the generic model can be used as a framework to understand the hypothetical complex and dynamic relationships of a number of variables important to the quality of the stroke care process. It demonstrates the potential benefits of an increase in the quality of the care plan, since that will increase the quality of the teamwork and in addition, the observation and assessment of a patient's health, which has an impact on the quality of the care interventions. The concepts and subsequent model structure are based on scientific evidence from several empirical studies of stroke care and STEs' knowledge, which strengthens the validity of the model.

The development of complex, clinical health care models is intricate, since many essential variables included in such models are qualitative. The relationships between variables are not usually presented as figures. Several care interventions are difficult to isolate in practice and consequently, a causal relationship responsible for an effect is difficult and sometimes not possible to study in isolation (Kalra & Langhorne, 2007). There are, for example, few studies of the relationships between a patient's participation and the influence on a patient's health (Florin et al., 2006). Furthermore, there is a lack of knowledge of the exact relationships between a documented care plan and the effect on

care quality (Ehrenberg et al., 2001). However, research has consistently shown that better outcomes in stroke care are associated with comprehensive and early processes of stroke-specific assessments and observations, particularly assessments for swallowing and aspiration risk, early detection and management of infections, maintenance of hydration and nutrition, early mobilization, clear goals for function, and communication with patients and their families (Evans et al., 2001: Indredavik et al., 1999). Stroke units appear to improve outcome by greater attention to stroke-specific medical, nursing and therapy processes and greater involvement of patients and their relatives. However, there is still a lack of knowledge regarding which of the interventions has the strongest influence on a patient's health (Kalra & Langhorne, 2007; Stroke Unit Trialists' Collaboration, 2007). For decision-making and analysis of stroke care, system dynamics may therefore be an important tool since it makes it possible to experiment with a model of hypothesized relationships.

In the present project, a model was developed in several steps to confirm the reliability and validity of the model. At the first stage, we developed the structure of the model together with a group that was designing a stroke unit. The cumulative knowledge from the group modeling workshops and evidence from the literature was transferred into a final causal loop model and was found to be an explicit, concise, and conclusive representation of their mental models (Elf et al., 2007). In the next step, stroke team experts at several hospitals were asked about the magnitude of the relationships in the model. After the development of the formal model, the team returned to the design group for scenario discussions. The model was presented for validity evaluation during the concluding meeting with the design group. A multitude of tests were performed in front of the group, which discussed and confirmed the results of each simulation that was run.

After this iterative modelling process, we are highly confident that the model is useful for the purpose of acting as a support tool in understanding and exploring the stroke care process. In addition, there is great potential to use the basic structure of the model for the further development of

care models for other patient groups.

However, we are aware of the models limitations, for example, that the magnitudes of the relationships between the variables in the model are estimated out from the literature and by STEs. The model does not include precise figures and thus, exact predictions of a patient's process to health are not possible to perform. In addition, some of the variables in the model need to be developed further. For example, the variable space quality needs to be more developed in the future. Still the model is an important first step which will facilitate further studies on the magnitude of the complex relationships in the stroke care process.

Conclusion and future research

The model presented in this paper is an interesting example of how modeling and simulation can be used in healthcare. The model is generic and used stroke care as an example. The model presented here was developed in a design process of a new healthcare setting with various stakeholders. The model has the advantage, compared to other conceptual models, of presenting stroke care as a complex system, with many feedback relationships between key variables. The design group was able to use the model in order to experiment and ask what if questions. The development of the model, with the contributions of existing literature and STEs, enables further tests in practice and hereby potential improvements in stroke care. In addition, there are opportunities to apply the model to other healthcare contexts.

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Dr. Elf received her PhD at the School of Architecture, Chalmers University of Technology, Sweden. In her thesis she used System Dynamic in designing new health care spaces. Her main research interest is in the area of health care spaces, the design process of new health care spaces and how to use new technologies to optimize the design process. Moreover, her interest is to bridging knowledge of caring sciences and architecture for creating spaces that support patient's way to health. Dr Elf is presently running a funded project (project leader)"Designing sustainable health care spaces for the 21st century". In this study we using modeling and simulation with System Dynamics and group-modeling in the building design process of new health care spaces. She is also a project leader for a study in which a valid and reliable instrument is developed for assess the content and quality in building programs (or briefs) created in the process of designing healthcare spaces.

FEATURE ARTICLE

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