Older adults and Health Related Quality of Life: a conceptual model based on dynamic systems

THIS IS A PRE-PRINT VERSION OF THE CHAPTER:

OLDER ADULTS AND HEALTH RELATED QUALITY OF LIFE: A CONCEPTUAL MODEL BASED ON DYNAMIC SYSTEMS

THIS CHAPTER IS PUBLISHED IN:
PSYCHOLOGICAL HEALTH AND NEEDS OF RESEARCH DEVELOPMENTS

HEALTH PSYCHOLOGY RESEARCH FOCUS

EDITOR RAUL WOLFE
NOVA SCIENCE PUBLISHERS INC.

ISBN: 978-1-63483-332-5
WEBSITE: novapublishers

OLDER ADULTS AND HEALTH RELATED QUALITY OF LIFE: A CONCEPTUAL MODEL BASED ON DYNAMIC SYSTEMS

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ABSTRACT

Ageing process involves the entire western world and in particular Europe. The analysis of demographic and health changes of the aged population is increasingly urgent in order to answer to the new individual and societal requests. An important concept in this regard is Health Related Quality of Life (HRQOL) during ageing, on which this paper will focus. Firstly, a general framework on demographics and health changes is provided. Secondly, the concept of HRQOL is analyzed, highlighting its strengths as well as its potential limitations. Thirdly, an analysis of HRQOL developmental trends, processes and mechanisms related to these processes is given. Finally, a conceptual dynamic systems model of HRQOL is delineated, in order to summarize the path taken in the paper and to propose new insights in the study of HRQOL in the aged population.

Keywords: Health related quality of life; Dynamic systems; Conceptual model; Ageing

1. DEMOGRAPHIC AND HEALTH CHANGES: A GENERAL FRAMEWORK

Europe is sometimes called “the old continent”. This statement becomes increasingly true, due to the ageing of the European population, which will have major effects on the global economical and societal systems and especially on public health, social needs, welfare state and economic policies. For this reason, it is important to analyze demographic and health changes of the ageing population in order to answer to the new needs of individuals and society.

In the lasts decades the concept of Health Related Quality of Life (HRQOL) became more and more used, due to its ability to focus on self-rated health status and perceptions, instead of simply using mortality and morbidity indicators. The concept HRQOL allows for a more encompassing and person-centered conceptualization of health outcome. However, currently it is not clear how HRQOL evolves during the ageing process.

This question can be answered by a comprehensive theoretical model that can structure the empirical data on the relevant health processes during ageing, and, by doing so, can form the basis for further studies on health prevention and promotion.

A comprehensive model of HRQOL has to: (i) include various domains of functioning; (ii) take into account the interconnections among domains; (iii) include predictable as well as unpredictable life events; and (iv) consider the variety of developmental processes, including stability, decline or improvement.

The paper will first describe the emergent ageing process, analyze the latest data on ageing-related changes, and highlight the relevant characteristics of HRQOL and its domains. As a next step, it gives an overview of what models we already have, and in what ways these models still lack the necessary characteristics. Finally, it will present a model that meets the requirements just mentioned, namely a model focusing on HRQOL from the perspective of Dynamic Systems theory.

Such an approach enables us to focus on processes acting on health status and perceptions during ageing, which is hardly possible with traditional approaches.

1.1. Demographic Changes

According to the World Health Organization and Eurostat, the aged population (65 years and over) will have a growth rate of 57% between 2008 and 2035, and of 80% between 2008 and 2060, rising from 84.2 to 151.7 million of older adults against a general EU population of 495.4 million of people in 2008 and 505.7 million in 2060 (Eurostat, 2011). Projections claim that, in 2060, almost 30% of European population will be over 65 years (Eurostat, 2008).

Longitudinal European data from 1990 to 2010 (Eurostat, 2011) describe an increase of 5.3% (20.6% in 1990 – 23.2 % in 2000 – 25.9% in 2010) of the old-dependency ratio, defined as the proportion between the number of seniors economically inactive and the number of persons in a working age. This means that in 1990 in the European zone, for any inactive aged person, five were economically active. Currently (2010) this proportion is 1 versus 4. Eurostat projections (Giannakouris, 2008) estimate an old-age dependency ratio of 52.5% in 2060.

Over the years, life expectancy (LE - the expected numbers of years remaining at a given age) increased considerably. Currently, LE at birth in Europe is 79.6 years (min 68 for Latvia - max 85 for France; Eurostat, 2011), with a strong increase from 76.5 years in 1999 (73 years for men and 80 for women) to 79.6 in 2009 (77 for men and 83 for women; Eurostat, 2011).

Unfortunately, the increase in LE is not accompanied by an increase in the Healthy Life Years (HLY), defined as the healthy life expectancy at a certain age. The European HLY followed a negative trend from 2004 to 2010 for both genders. In particular, HLY at birth was 63.7 years for women and 62.2 years for men in 2004. In six years, it decreased with 1.1 years for women (62.6 years) and 0.5 years for men (61.7 years). If compared with LE data at birth the values highlight an average of 20 unhealthy years for women (82.6 – 62.6) and 15 years for men (76.7 – 61.7).

The WHO General Director, Dr. Hiroshi Nakajima, in 1997, said: *"Increased longevity without quality of life is an empty prize. Health expectancy is more important than life expectancy"*. The widening gap between quality of life and longevity is paid on an individual level in terms of loss of autonomy and institutionalization, and on a societal level with a higher demand for care and increasing of National Health Systems costs.

To cope with these demographic and social changes and to try to add life to years (and not only years to life), the objectives of both researchers and clinicians are: (i) to identify processes and mechanisms underlying changes of health status and quality of life in the older adults population; and (ii) to implement effective preventive interventions in seniors, in order to maintain health status and autonomy as long as possible. In the next sections, we will give a short overview of what is known about age related changes in health.

1.2. Age-Related Health Changes

At first sight, data discussed in the previous section, confirm the expansion of morbidity theory (Manton, 1982). According to this theory, increase in LE is caused by a lower death rate for chronic diseases rather than by a decline in the incidence of these diseases. This view highlights that increasing longevity is related to increasing number of unhealthy-years.

Conversely, the dynamic equilibrium theory is based on the decrease of the impact of diseases on the health of older adults (Manton, Gu, & Lamb, 2006, Manton, 1982). This theory assumes that the lower mortality is linked to a less deterioration of the vital organs, and that diseases have a lower severity (Crimmins, 2004), however do not assume a lower incidence of pathological conditions.

The reduced impact in terms of disability (Crimmins, 2004) is not accompanied by a decrease of incidence and prevalence of chronic diseases in the seniors (Eurostat, 2011; Marengoni, Winblad, Karp, & Fratiglioni, 2008). In fact, statistics from Eurostat (2011) show that the percentage of people having an enduring illness or health problems in the European area is higher with the increase of age: 30.9% in the whole population, 54.8% in the population aged 65-74, 66.1% in the 75-84 years population and 69.5% in the over 85 years. This trend is increasing from 2004 to 2010, proportional to age: 3.2% in the whole population, 4.5% in the population aged between 65-74, 5.4% in the 75-84 age group and 6.1% in over 85 years (Eurostat, 2011). The high prevalence of non-communicable and other chronic conditions in the aged population is the most relevant cause of unhealthy years in later life.

Starting from the WHO definition of Health (1946): *''Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'',* it is possible to analyze health changes typical of ageing process in each of the three domains (physical, mental and social) proposed by WHO.

Physical health changes are related to muscle-skeletal (Cummings, 1993; Doherty, 2001; Frontera, et al., 2000; Hannan, et al., 2000; Janssen, Heymsfield, Wang, & Ross, 2000; Johnell & Kanis, 2004; Lexell, 1995; Rogers & Evans, 1993), cardiorespiratory (Janssens, Pache, & Nicod, 1999; Kitzman, 2000; Kitzman & Edwards, 1990; Rossi, Ganassini, Tantucci, & Grassi, 1996; Rossi, et al., 1996; Sharma & Goodwin, 2006), and nervous systems (Albert & Janice E. Knoefel, 1994; Rivner, Swift, & Malik, 2001; Salat, et al., 2004), that may have negative impact on health outcomes, autonomy of daily living and HRQOL (Chien, Huang, & Wu, 2008; Janssen, Baumgartner, Ross, Rosenberg, & Roubenoff, 2004; Janssen, Heymsfield, & Ross, 2002; Roubenoff & Hughes, 2000).

In the mental domain, changes were found on cognitive (Mebane-Sims & Association, 2009; Small, Stern, Tang, & Mayeux, 1999) and psychological adjustments (Beekman, Copeland, & Prince, 1999; Beekman, et al., 1998; Blazer, Burchett, Service, & George, 1991; McAvay, Seeman, & Rodin, 1996).

Finally, the social domain shows changes in and disengagement from social activities during the ageing process (Bennet, 2002; Cumming & Henry, 1961).

1.3. Successful Ageing

On the one hand the physical, mental and social changes are described as decline and disengagement from usual activities (this view is generally called usual ageing, see Atchley, 1989), on the other hand, the new and more positive thinking (successful ageing, see Baltes & Baltes, 1993)) proposes an increase or maintenance of health status in the older adult population due to changes that occur in daily habits and lifestyle (i.e., participation in activities). A recent study (Haskell, et al., 2007) shows that an active lifestyle and/or a participation in physical exercises may lead to an improvement in physical fitness, health status and diseases prevention.

An active lifestyle is also correlated with a better cognitive and psychological health (Floel, et al., 2008; Netz, Wu, Becker, & Tenenbaum, 2005), with important consequences for prevention of health decline, functional loss and disability (Fratiglioni, Paillard-Borg, & Winblad, 2004; Keysor, 2003). In contradiction with disengagement theory, activity theory (Lemon, Bengtson, & Peterson, 1972), supports the active participation of seniors in social life. This participation can be beneficial to health, with a consequent reduction of mortality (Bennett, 2002; Sabin, 1993).

Finally, the Selection, Compensation and Optimization Theory (SOC) proposed by Freund and Baltes (1998) explains in a positive view on the ageing process. SOC theory expresses ageing as a complex, multifactorial process, not understandable from a linear perspective (Baltes & Smith, 2003). In addition, the approach of Baltes identifies ageing not only as a period of decline but also as a life-phase in which individuals can find new ways and strategies to maintain their normal life.

1.4. Interplay among Domains

In order to understand age related health change, one of the most important aspects that emerged in the literature is the strong connection between the physical, psychological and social domain. It was demonstrated that changes in one of the health components affect the other domains directly or indirectly. Interconnections among health domains were found between (i) physical and mental (Bouchard & Shephard, 1994; Kramer, et al., 2003; Wang, Larson, Bowen, & van Belle, 2006); (ii) psychological and social (Glass, De Leon, Bassuk, & Berkman, 2006; Kawachi & Berkman, 2001); and (iii) physical and social components (Bennett, 2005; Bennett, 2002). These relations, which require further investigation, reflect the complex interplay among health components, confirming the basic assumptions of the biopsychosocial model (Engel, 1977). The biopsychosocial model is in contrast with the classical biomedical model, in which “health” is a category opposite to the category “infirmity”. Furthermore, the biopsychosocial model considers interconnections and mutual influences among health domains, with the use of a systemic approach, based on systems theory (Engel, 1977). The biopsychosocial model allowed to study health and health-related topics as systems of interconnected elements, that may vary and change over time in a continuous way.

In order to understand the complex interplay among health domains, a model that considers mutual relationships, focusing on changes and non-linarites, is needed. A dynamic systems approach can be very helpful to conceptualize and study such a complex, non-linear process. It offers possibilities to analyze the mutual connections and development of HRQOL over time that are not possible with more classical approaches. Dynamic systems focus on the components of the system and their mutual influences (Kunnen, 2012).

2. The Concept of Health Related Quality of Life: Definition and Limitations

The construct of HRQOL is suitable for the purpose of studying health process during ageing, because it addresses self-rated health, and because it is a predictive measure of health decline, mortality and institutionalization in the aged population (Bilotta, et al., 2011; Dorr, et al., 2006).

HRQOL is a concept deriving from two sources. The first is the definition of health previously cited (Age-related health changes section). The second is the definition of quality of life (QOL) as -“the subjective perception that an individual has of his own existence, in the context of culture and of a set of values in which he lives, even in relation to his objectives, expectations and concerns”) proposed by WHO (1997).

2.1. A definition of HRQOL

HRQOL is a person centered measure that can be modified in a complex way from (i) perceptions of physical and psychological-emotional health; (ii) level of independence; (iii) social role; (iv) relationships; (v) context; and (vi) environmental and working interactions (Testa & Simonnnson, 1996). HRQOL refers to physical, mental and social domains of health that are seen as distinct areas influenced by a person's experiences, beliefs, expectations, and perceptions (Testa & Simonson, 1996). HRQOL narrows the focus to the effects of health, illness, and treatment on QOL, and excludes aspects of QOL that are not related to health, such as cultural, political, or societal attributes (Ferrans, Zerwic, Wilbur, & Larson, 2005).

2.2. Limitations of the Current Conceptualization

The distinction between health-related and non-health-related quality of life is not always simple, and for this reason many models exist that include different aspects of HRQOL. For instance, Wilson and Cleary (1995) created a model based on biological/physical variables, symptoms, functional status, health perceptions and overall QOL, with the addition of individual and environmental characteristics. Other scholars suggest six fundamental dimensions of HRQOL: physical functioning, psychological functioning, social functioning, role activities, overall life satisfaction, and perceptions of health status (Berzon, Hays, & Shumaker, 1993). Patrick and Erikson (in Aaronson, 1993) use a model composed by five concepts: life span, symptoms, physical functions, health perceptions and opportunity. Ware and Dewey (2000) analyzed HRQOL as a series of concentric circles that spread from biological functions to HRQOL via physical/mental health and social role. Other models include physical problems, psychological problems, sexual functions, activity of daily living and perceptions of wellbeing. The only common point among these models is the multidimensional nature of the concept.

Furthermore, for model building and comparison, also the modes to assess HRQOL have to be taken into consideration. Bury and Holme (1991) and Testa and Simonson (1996) argue that each dimension can be measured in an objective and subjective way. While the objective measurement refers to health status, the subjective evaluation is related to the perceptions of health, implying that two persons with the same health status may have different HRQOL's. This implication is supported by Henchoz et al. (2008), who found differences between health status and health perceptions among older adults, confirming the importance to assess both aspects.

The most used and detailed conceptual model of HRQOL is the one proposed by Wilson & Cleary (1995). This model conceptualizes HRQOL as a continuous and linear path from the biological functions to the overall QoL (via symptoms, functional status and general health perceptions). Furthermore, each concept included in the Wilson & Cleary model has a direct influence from the individual and the environmental characteristics. This model represents a uni-directional causal approach, based on the biomedical model (opposite than the biopsychosocial model, that allow a nonlinear multidirectional causal approach) to the analysis of HRQOL.

Although the model gives important information about the elements acting on the HRQOL, there are various limitations. The first regards the concepts of development and changes of the construct under examination. HRQOL is a concept that arises from the match between health-status and health-perceptions factors and this procedure can be seen as an ongoing, iterative process, in which a subsequent state is strongly connected with the previous one. The conceptualization of the development of HRQOL as linear is theoretically not plausible, and it does not fit in with empirical findings. It is therefore necessary to emphasize the role of time and the iterative process in self-assessment of HRQOL. Second, the Wilson & Cleary model shows limitations regarding the interconnections among domains/variables, which it primarily conceptualizes as a structure of uni-directional links. A single direction for the links among the elements can lead to neglecting the possible interconnections and the complexity of the structure. Third, the causal model of Wilson & Cleary (1995) insufficiently accounts for the particular influences of random events. Casual events can act on each component of the models and are not presented in the conceptualization. To avoid the loss of a source of information that acts directly on HRQOL domains, the inclusion in the conceptual model of random influences is necessary.

2.3. A Step Forward in the Definition of HRQOL

Due to the lack of consensus among models, we think that it is useful to formulate the conditions and sketch the outlines of a new and more comprehensive conceptual model of HRQOL. In particular, our aim is to adopt a three dimensional structure, using physical, mental and social domains (starting from the WHO definitions of Health). The three dimensional structure is to make the model consistent with the WHO definition, but also because we need a simply, understandable and comprehensive definition and conceptualization of HRQOL and its their main domains. Moreover, we aim to use a double way of assessment (as proposed by Testa and Simonson, 1996) in order to capture both status and perceptions of each dimension.

The advantage of this theoretical structure is based on the usefulness and easiness to adopt the tripartite nature of health as proposed by WHO, thus avoiding the use of many different domains that hinder the comparison of the results based on assessment instruments using a more complicated definition of HRQOL (Murdaugh, 1997). Furthermore, the adoption of Testa and Simonson's distinction between the health-status and health-perceptions components of HRQOL, offers the possibility to understand differences in HRQOL, and to provide new ways of explanation of changes and intra- and inter-individual variability.

2.4. Strengths of the Concept

Despite the lack of consensus on HRQOL definitions, the usefulness of a HRQOL measure in clinical and research fields is widely recognized.

HRQOL provides a patient point of view on effects of interventions, diseases and processes acting on people. It is a person-centered outcome measure, which is more specific and indicative, then the traditional measures of mortality and morbidity (Idler & Benyamini, 1997; Tsai, Chi, Lee & Chou, 2007).

HRQOL is important on both the individual and the societal level. On the one hand, it is important to assess HRQOL, with the goal to enhance the healthy life expectancy (Theofilou, 2011). On the other hand, measure HRQOL is recognized as an objective that must be reached by the US program Healthy People 2020 (U.S. Department of Health and Social Services), and will help nations in monitoring to what extent health objectives have been achieved (Theofilou, 2011).

3. Developmental Trends of HRQOL in the Aged Population

In previous research, HRQOL is mainly used as an outcome measurement that indicates the impact of processes (i.e., pathological processes) on self-rated health. Specifically, previous literature reports two types of studies on HRQOL and aged people, about: (i) the impact of diseases, (ii) the impact of activities/behaviors/interventions. In the first case, scholars reported the negative impact that different kind of diseases have on HRQOL.

In particular, chronic diseases, such as hypertension, osteoarthritis, diabetes, depression, asthma are the most studied (among other: Kempen, Ormel, Brilman, & Relyveld, 1997; Lam & Lauder, 2000). Research reveals the general negative trend that diseases and comorbidity have on HRQOL of older adults (Hopman, et al., 2009). Furthermore, the mental component was seen as the most stable, that seems to maintain its level also in the presence of various diseases (Hopman, et al., 2009; Kempen, Ormel, Brilman, & Relyveld, 1997).

Other studies (Lam & Lauder, 2000; Lima, et al., 2009) show that some diseases may affect a variety of aspects: hypertension affects the physical component in particular, asthma and joint diseases are negatively associated with autonomy in activities of daily living. Depression is a condition that highly affects the whole HRQOL (Lam & Lauder, 2000).

Secondly, evidence on the effects of various types of independent variables on HRQOL affirms that there is a strong relation between active lifestyle (i.e., active leisure time, hobbies, participation in specific interventions) and HRQOL. In particular, previous studies highlight that people who are physically active during leisure time have a higher level of HRQOL in comparison with sedentary older adults (Balboa-Castillo, Leon-Munoz, Graciani, Rodriguez-Artalejo, & Guallar-Castillon, 2011; Drageset, et al., 2009; Jenkins, Pienta, & Horgas, 2002; Lee & Russell, 2003; Thompson, Zack, Krahn, Andresen, & Barile, 2012).

Recently, various interventions were compared on their effectiveness for HRQOL. Excluding drug trials, the most common are physical and psychological/cognitive interventions.

Cognitive interventions, based on memory, reasoning or speed of processing exercises, (among others: Wolinsky, Unverzagt, Smith, Jones, Stoddard, et al., 2006; Wolinsky, Unverzagt, Smith, Jones, Wright, et al., 2006) demonstrated their efficacy in terms of maintenance of HRQOL.

Various types of physical training showed beneficial effects; in particular, scholars reported the effectiveness on HRQOL of: strength exercises (Kimura, et al., 2010), combined strength and endurance exercises (Sillanpaa, Hakkinen, Holviala, & Hakkinen, 2012), and aerobic exercises (Ciairano, Liubicich & Rabaglietti, 2010; Deschamps, Onifade, Decamps, & Bourdel-Marchasson, 2009). All interventions have positive effects on HRQOL, compared with non-participants groups. In sum, the literature provides strong evidence for positive effects of general physical activity interventions on HRQOL (Acree, et al., 2006; Elavsky, et al., 2005; Inaba, Obuchi, Arai, Satake, & Takahira, 2008; Lee, Lee, & Woo, 2009; Penedo & Dahn, 2005; Shephard, 1993; Sillanpaa, et al., 2012; Yasunaga, et al., 2006).

Moreover, a study of Deschamps et al. (2009) compared a physical training based on Tai Chi exercises and a cognitive training, emphasizing that both interventions directly and positively act on HRQOL of participants. Another study, based on Shintaido discipline, combining mental and physical activities, demonstrated the ability to act directly and indirectly on physical and psychological health of older adults (Roppolo, Mulasso, Magistro, Roggero, Andreoli, & Liubicich, 2012).

Thus, there is a lot of research showing that HRQOL can be affected by a variety of processes. However, little attention has been paid to the developmental changes of HRQOL itself.

In our view, HRQOL is not just an outcome, but it is a process itself, resulting from iterations and interconnections among domains.

It seems that HRQOL is a construct characterized by complex variability, modifications and variations caused by individual characteristics, activities, behaviors and social interactions. Currently, scientific evidence clearly showing developmental trends of HRQOL in the ageing process is inconsistent. Moreover, no models take into account the role of time with regard to changes in HRQOL.

Longitudinal studies are needed to explain the role of time. Cross-sectional data reported a general decrease of the physical component with the increasing of age, while the mental component seems to remain stable (Hopman, et al., 2000). Nowadays, due to the lack of studies exploring trends of HRQOL over time, it is fundamental to build a theoretical framework in order to conceptualize HRQOL as a person-centered system composed by a set of interconnected elements, that develop during time as results of the iterations and internal/external influences. The resulting conceptual model will be useful to: (i) better understand processes and mechanisms of changes in HRQOL during the ageing process; and (ii) analyze individual developmental trajectories. This approach may allow a better comprehension of the process modifying HRQOL, and may provide effective and individualized interventions for health promotion in seniors.

4. HRQOL AND DYNAMIC SYSTEMS

The main objective of this paper is to present a new conceptual model of HRQOL that allows for understanding the change processes in the aged population. Currently, models use a large variety of components that do not allow comparability among them. Interconnections among domains, role of time and life events are not considered. Finally, the current models are linear and confine themselves to uni-directional causal relationships.

In our view, HRQOL is a system, and as a system has to be studied as a whole, in order to understand its development over time. To delineate such a system, dynamic systems represent a solid basis.

The new conceptual model aims to take into account the development of the construct and the individual trajectories of HRQOL over time. In particular, the new HRQOL conceptual model will consider the role of time, the causal interconnections among variables/domains and the influences of random effects.

The dynamic systems approach has been already applied in the field of social sciences and developmental psychology in the analysis of psychological characteristics, mainly in childhood and adolescence (Bassano & van Geert, 2007; Kunnen, 2009; Kunnen, 2012; Lichtwarck-Aschoff, Kunnen, & van Geert, 2009; Steenbeek & van Geert, 2008; van Geert, 1994). The present article aims to extend this literature, applying a dynamic systems approach on the construct of HRQOL in a population of seniors (generally not considered in the psychological dynamic systems studies). Before doing so, we will describe the most important features of dynamic systems and discuss how the concept of HRQOL fits in with these features.

4.1. General Characteristics of Dynamic Systems

A dynamic system is composed by a set of interconnected interacting elements that affect each other. These interactions provide the causal ground for the development of the system during the course of time (van Geert, 1994; Weisstein, 2003). The dynamic systems approach to human development is based on the view that humans are complex and interactive systems that change (or develop) their state (for instance, their emotional state) during time. Development derives from interactions among environmental and individual variables and inter-individual characteristics (Kunnen, 2012; Kunnen & Bosma, 2000). In particular, the focus of a dynamic systems perspective is the analysis of individual changes and trajectories over time (Thelen & Ulrich, 1991), emphasizing the role of intra-individual variability and stability as fundamental notions to understand the development of the systems (Thelen & Smith, 1996; Thelen & Ulrich, 1991; van Geert & van Dijk, 2002). Development may emerge on a long-term time scale (changes that occur over the course of months or years), and on a short-term time scale (short time period representing actions on a real time basis; Kunnen, 2012). Furthermore, the process of individual changes, that represents the main objective of the dynamic systems studies, is complex and multivariate (Kunnen, 2012). Complexity involves mutual causality among interconnected components, which results in self-organization and emergent phenomena. Self-organization is defined as the emergence of a stable higher order characteristic in the system (Kunnen, 2012).

4.2. Can HRQOL Be Viewed As a Dynamic System?

Starting from dynamic systems theory and the current conceptualization of HRQOL, it is plausible to assume that the latter shares important characteristics with the former.

4.2.1. Developmental Process

HRQOL is assumed to show intra-indiviudal change over time (Bernhard, Lowy, Mathys, Herrmann, & Hurny, 2004; Sprangers & Schwartz, 2008). Especially, it tends to show a decline in the ageing period. The decline may be gradual or by sudden steps. Furthermore, HRQOL may show temporary increase or fluctuations. For these reasons, it is possible to hypothesize that HRQOL is a developmental process described as a sequence of states over time. Each state of the system in any time is described by the position of the relevant dimensions of the system itself (Kunnen, 2012). The position of the system in the space of relevant dimensions changes over time, and the sequence of such positions draws a path through the developmental space. The path described by the relevant dimensions over time represents the developmental process. Development, in this sense, is an iterative process. Iterative means that each step in the developmental path is related to its previous state (the starting value of a step is the outcome of the previous one).

4.2.2. Interconnected Elements

Existing definitions and conceptual models agree that HRQOL is a multidimensional construct (Lipscomb, Gotay, & Snyder, 2004). Interconnections among elements are a typical characteristic of systems in the human and social sciences. Each HRQOL component can influence, change or act on the other. As an example, mental health can influence both the physical and the social functions (i.e., the case of depressive symptoms). The interconnections among elements represent another similarity between HRQOL and dynamic systems theory.

4.2.3. Non linearity

Living systems are in general nonlinear (Kunnen, 2012; van Geert, 2008). This statement is mainly attributable to the impossibility for a human system to always proceed along continuous and stable trends (e.g. continuous and constant growth of health perception), assumption related to linear systems and their additive nature of the contribution of distinct variables. In HRQOL many factors (i.e., diagnosis of a disease, administration of a new drug) can reverse or change the growth rate of the health status. Nonlinearity is also related to the number and types of influences (internal and external) to which every person is subject. In particular, mutual influences, including iterativity causes processes to become nonlinear. A very important source of nonlinearity is the fact that many processes are time dependent, (i.e. dependent on their own history) which is a major feature of an iterative process.

HRQOL, conceptualized as a system of interconnected elements that develop during time, can be expected to show nonlinear behavior over time. The interconnections among elements imply that changes in the trend of one component can influence the trends in other domains, which can feed back onto the first component.

4.2.4. Mutual Causality

An important characteristic of complex and non-linear systems is that unidirectional and proportional (linear) causal relations between two variables are relatively rare or unlikely. Sometimes, a small change in one variable may cause a big change in the whole system. Other times, repeated and strong attempts to modify the system are without effect. Human systems are, characterized by the impossibility to predict the sequence of outputs, knowing the sequence of inputs and the initial state of the system. In non-deterministic systems, each initial state and inputs value correspond with lots of possible output states. As an example, the therapeutic effect of the same intervention may have different level of efficacy in two comparable individuals, with strongly beneficial effects for one of those and completely inefficacy for the second one.

Initial conditions, mutual causality and randomness play a strong role in these relationships making the prediction almost impossible.

For these reasons, health status and in particular HRQOL may be treated as non-deterministic systems.

4.2.5. Transitions

Transitions are important phases in the development of a Dynamic System. A transition phase is a period in which the system changes from one stable state to another stable state. The change can be attributable to modifications in its components or in their interconnections, or to the emergence of new relevant variables (Kunnen, 2012). In particular, in a transition phase, the components of a system can become more or less influential to the whole system. Some of these variables could be excluded and other variables could be added into the system. However, it is important to notice that not all the dynamic systems shows transition phases in their development.

Referring to HRQOL in the older adults population, the loss of a specific ability (e.g., walking autonomously) or the changes of habits due to health conditions (e.g., institutionalization) could be seen as transition phase, in which the whole system modifies its nature, and in which the person need to modifies his habits, lifestyle and activities. These changes may disturb the whole system before the creation of a new phase of equilibrium (different from the previous one).

Transition periods are accompanied by increased or uncommon variability that can be followed by a new and generally different stable condition (Kunnen, 2012).

4.2.6. Variability

Transitional phases are usually preceded by period with high and strange variability (van der Maas & Molenaar, 1992). Real and living systems are open and unstable systems, due to their interactions with the environment. Interactions with the environment and with other open systems (e.g., people) produce variability in the state of a system (Kunnen, 2012; van Geert & van Dijk, 2002). However, variability is not linearly related to the strength of the influences from the environment and open systems. Instead, it is dependent of the state of the system, regarding the vicinity to a stable self-sustaining state (attractor).

Also in this case, the concept of HRQOL, in particular in the older adults population (highly influenced by internal and external sources), fits in with this feature. It is an example of a system that may show high intra and inter individual variability (Wyrwich, 2000; Browne, 1994). The amount of variability provides important information about the developmental behavior and the state of a system. In particular, too high or too low variability may results in catastrophe or indicate problems within the system (Hollestein, 2004; van der Maas & Molenaar, 1992).

Summarizing, HRQOL seems to meet the features of a dynamic system. A dynamic systems concetualization may solve the limitations of the existing models.

4.3. A Conceptual Model of HRQOL Based on Dynamic Systems

The dynamic systems conceptual model of HRQOL (DSCM-HRQOL) aims: first, to apply theories and methodologies typical of dynamic systems; second, to employ the specific terminology proposed by WHO to define health, in order to create uniformity between the official definition of health and the modeling of theories; third, to apply the conceptualization proposed by Testa and Simonson (1996) for the evaluation of health-status and health-perceptions of each component of HRQOL. The use of the double evaluation dimension solves the limitation that the conceptualization and measurement of HRQOL health status and perceptions follow an increasing gap during the ageing process, and that people aged over 80 tend to underestimate the HRQOL decline (Henchoz, et al., 2008). In this way, a more comprehensive assessment may be more precise.is either a person's health and functional status or his perception of wellbeing, giving it a more complex and systematic quality. In our view, Tthe two components of each domain may be collected separately, offering the opportunity to explore dynamic relations between these components. However, since HRQOL is mainly oriented to the subjective and individual judgement of its own health, it was decided that both the health-status and health-perceptions dimensions will be detected by self-report indicators.The DSCM-HRQOL will focus primarily on the aged population, with the aim to tackle loss of health and functionality. Nevertheless, the feasibility of the new model of HRQOL may be extended to the whole population or to specific sub-groups.

This section will move firstly with the definition, operationalization and assessments of the principal domains of the model, secondly, it will proceed with the definition of the other components of the model and finally, the structure of the whole conceptualization will be defined.

4.3.1. Domains of DSCM-HRQOL

Physical Domain - Definition

The physical domain of HRQOL refers to the ability of performing physical efforts and carrying out work, in order to have autonomy in ADLs and to maintain a state of physical functioning appropriate for social and environmental demands. Our view of physical health emphasizes functions, (such as walking, climbing stairs, bathing etc.). By doing so, we follow the key concepts proposed by the International Classification of Functioning, Disability and Health (ICF) by WHO, instead of focusing mainly on limitations, as previously conceptualized (Kaplan, Bush, & Berry, 1976; Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963; Ware, 1987).

Physical Domain – Operationalization

The physical health-status assessment with the use of self-report questionnaire must to be centered on physical performance (total amount of activities performed; Leidy, 1994), because it is impossible to measure physical capacity with such instruments. One of the most reliable instrument is the International Physical Activity Questionnaire (Booth, et al., 2003) previously used in aged sample (Tomioka, Iwamoto, Saeki, Okamoto, 2011).

The health-perceptions component of physical domain may be assessed with self-report questionnaires. The physical well-being scale of the Quality of Life Questionnaire (Evans, Burns, Robinson, & Garrett; 1985) is an example.

Finally, some validated questionnaires (i.e., the Short Form-36, Physical Composite Score) allow to assess a composite score of the physical domain. These questionnaires can be used to obtain general information about the physical domain, however, they do not capture the health-status and health-perceptions component separately.

Mental Domain - Definition

WHO (2011) defines mental health as: "*a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community*". Furthermore, MedLine Plus (U.S. National Library of Medicine, National Institute of Health) highlights that mental health "*affects how we think, feel and act as we cope with life. It also helps determine how we handle stress, relate to others, and make choices. Mental health is important at every stage of life, from childhood and adolescence through adulthood*".

Referring to the older adults population, the evaluation of the mental domain can be subdivided in: (i) psychological; (ii) and cognitive assessment.

Mental Domain – Operationalization

As previously cited (section Age-related health changes), the most important mental characteristics are related to the cognitive and psychological area.

In order to measure the health-status component of the mental domain, instruments of cognitive and psychologicalassessment may be done with the Mini Mental State Examination (Folstein, Folstein & McHugh, 1975), mainly used in the aged population. In the psychological area, the focus may be oriented on the measurement of depression (i.e., Geriatric Depression Scale; Yesavage et al., 1983), anxiety (i.e., Geriatric Anxiety Inventory; Pachana et al., 2007) and, self-efficacy (i.e. General Self-Efficacy Scale; Bosscher & Smit, 1998).

Moreover, the health-perceptions component can be measured with scales for the assessment of mental well-being (i.e., Warwick-Edinburgh Mental Well-being Scale; Tennant et al., 2007), previously used among older adults (Gale, Dennison, Cooper, Sayer, 2011).

Finally, also for the mental domain, some instruments (i.e., Short Form-36, Mental Composite Score) generate a composite score including health-status and health-perceptions oriented questions.

Social Domain - Definition

The social domain of our model refers to the ability of a subject to maintain his social engagement despite the ageing process. The maintenance of engagement with social life represents a protective factor (Bath & Deeg, 2005; Garcia, Banegas, Perez-Regadera, Cabrera, & Rodriguez-Artalejo, 2005) for the decline in health status and should be included in the assessment.

This ability could be assessed with measurement of social network (size) and relationships (frequency and intensity).

Social Domain – Operationalization

The social domain may be divided in an objective component, seen here as the size of the social network, and a subjective component, intended as the quality of social relations.

In particular, the health-status oriented component (social health status) may be measured with questionnaires that analyze the social network size, as the Lubben Social Network Scale (Lubben, 1988).

In addition, the health-perceptions component may be evaluated with questionnaires built to analyze the quality of the social relations, such as the Friendship Quality Scale (Hawthorne, 2006), also previously used in ageing-related studies.

4.3.2. Assessments of the Domains

If we assume that HRQOL is a dynamic system that develops during time, it is necessary, after the definition and operationalization of its domain, to define how to assess and how capture the dynamic nature of such a construct.

The dynamic systems approach assumes that time is a core characteristic of the system itself (Kunnen, 2012), and in this view it is possible to observe how the system develops at different and interconnected time levels (Kunnen, 2012). Specifically, dynamic trends are detectable from very short time scales (microlevels) to very long time scales (macrolevels), all related each other, in the sense that dynamic characteristics at the microlevel influence the development at the macrolevel. The analysis of development at different time scales was previously studied and analyzed in other areas of research, defining how long-term development shapes and is shaped by everyday events (Lichtwarck-Aschoff, van Geert, Bosma, & Kunnen, 2008; Kunnen, 2012).

The use of an assessment at different time levels may be suitable also in the case of HRQOL. Specifically, such an approach gives us the possibility to match the long-term trends (i.e. the analysis of data points month away from each other) with the analysis of short-term trends. The analysis at microlevel of the indicators of the three main domains, measured very often, or sufficiently often, (i.e., day-to-day assessments) allows to detect a time series of data with which we can specify individual trajectories, including intra-individual variability. The use of such an approach may lead to a better understand of the short-term changes in the HRQOL, with the possibility to better understand also long-term trends and outcomes. In other words, a dynamic systems approach helps us to understand how long-term development of HRQOL, important indicator and predictor of negative health outcomes, emerges out of short-term (day-to-day) interactions.

The assessment of HRQOL at a short-time level, will need the set-up of a series of indicators (covering both the health-status and the health-perceptions components) that allow an easy collection and in the meanwhile, that may be representative of the construct.

4.3.3. Additional Components

The three domains form the core of the dynamic systems model of HRQOL. However, to formulate a complete model, we need to specify several additional components.

Stable individual parameters

Individual parameters are essential information in complex and dynamic systems (Smith & Thelen, 2003). In particular, also weak differences in the initial condition of a system can cause a great discrepancy in the developmental trajectories or in the final state (De Toni & Comello, 2005; Kunnen, 2012). For these reasons, in addition to the baseline evaluations of the three HRQOL domains, we include in our model indicators of individual parameters, which can have a considerable impact on the trend of the construct under investigation, as it unfolds in a particular individual person.

More specifically, the indicators inserted in the model are: (i) age, due to high correlation between ageing process and health decline; (ii) presence and type of morbidity, directly affecting HRQOL; (iii) lifestyle habits (protective and risk factors).

These indicators can be aggregated to create a general index of stable individual parameters, which will have a direct influence on the baseline assessment of each domain.

Random Influences

In the model, we included also a stochastic influence that can act on physical, mental and social domains of HRQOL. As previously cited (see section Non causality), living systems are subject to unpredictable and uncontrollable effects of random events (Kunnen, 2012). Random influences are a fundamental source of information in modeling of reality, especially in dynamic systems models, because in such a models the idiosyncratic nature of the random influences is a central feature, since every system is conceived as a network of interacting components, and the interaction rules are typical of the individual subjects. Furthermore, the inclusion of random influences can be useful for future translations of the conceptual model into a mathematical model.

In our DSCM, random influences may affect each of the three domains of HRQOL, and are seen as unpredictable events of everyday life. Some examples are the onset of a disease, an adverse physical situation (i.e., a fall) but also the consolidation of a friendship relation, the birth of a grandson or a new interest/hobby. All these aspects, completely unpredictable, nonlinear and idiosyncratic, influence the whole system and can explain trends and transitions.

4.3.4. Architecture of DSCM-HRQOL

After the explanations of domains included in the model, the next step in designing a conceptual model is to depict its relations during time and among components.

Developmental Process (Role of Time)

The DSCM-HRQOL is a developmental model. The aim is to delineate the evolving patterns and trends of HRQOL during time as they occur in individual subjects. As mentioned previously, developmental systems are iterative, following a process which takes place step by step and in which the outcome of a previous step is the input value for the next step (van Geert, 1994). In our conceptualization, the three central domains of HRQOL follow these rules, evolving during time in the form of an iterative process. Iterativity implies interdependency among measures (e.g., A depends on B and B depends on A, or, physical health depends on mental health, and mental health depends on physical health).

As a simple exemplification of the iterative behaviors, we can imagine an older adult who one day by chance meets one old friend. The unexpected social contact might have an immediate short-term positive effect on the persons feeling of social well-being. This temporal increase might result in the person's decision to increase the intensity of these social contacts, which might lead to consolidation of the short-term increase in social well-being. Other examples could imply the reduction of the daily physical activity after a fall, with a consequent decrease of the HRQOL in the physical domain, or an increase in performing memory games after becoming aware of a decline in cognitive functions.

This example shows that the connections between different domains occur on the microlevel of one iteration. The dynamic development starts with the events on the microlevel. Most of these events at the microlevel consolidate the person’s stable state (attractor), but some may lead to other attractor states.

Our model describes how the different domains affect each other on the level of one iteration. However, one iteration leads to a set of consequent iterative steps that lead to changes in the person’s attractor state.

The basic structure of a dynamic systems model consists of iteration descriptions (in a mathematical model these are translated into differential equations) between the domains. The iterative character implies that these connections or equations are repeated again and again, and in this way, they describe the development of the different domains over time.

Interconnections

The upper box included in the model (see Figure 1) is the stable individual parameters of each of the three domains. In other words, it is the condition from where the model starts to simulate further behaviors. The three domains of HRQOL, representing the central body of the model, are fully interconnected.

Arrows connecting the same domain at different times represent the influence of the previous condition of that domain on the condition in the next iteration.

Influences are delayed, meaning that arrows do not link two domains at the same time because, in our vision, the effect of one domain on another domain will be visible in the next situation. Regarding HRQOL among seniors, we hypothesize that process of change can be seen from a daily basis.

Finally, each domain at every time level is connected with a random influence (R) that represents the casual and unpredictable part of the model.

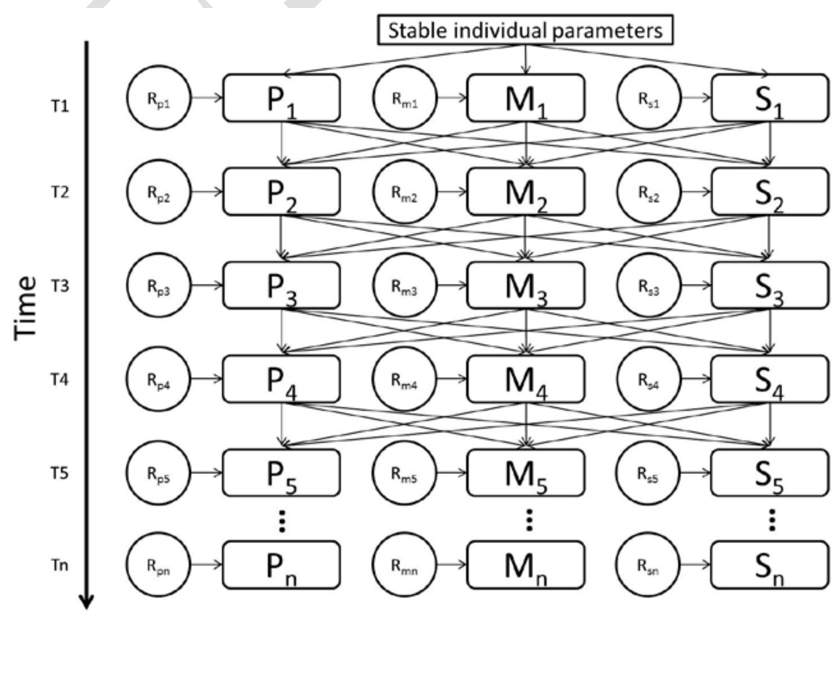

Figure 1. - The Dynamic Systems conceptual model of HRQOL

Stable individual parameters is an indicator of age, comorbidity and lifestyle, directly influencing the three main domains of HRQOL.

P= physical domain

M= mental domain

S= social domain

R= random influence

The model shows 6 iterations (from T1 to a generic Tn), each arrow is a connection between domains during time

The model that is presented here is a theoretical model. It is built upon existing knowledge, and it aims to integrate the merits of existing models, adding the developmental perspective. Contrary to earlier models, it allows to study and analyze changes in the construct as a result of the iterations among domains, explicating the possible mechanisms acting during the development of the construct.

The model described here meets the basic requirements described in the beginning; it takes into account: (i) the different domains that are relevant in HRQOL; (ii) the developmental processes that result in stability or change in HRQOL; (iii) the influences of each domain on the others; and (iv) the influence of unpredictable events. The model may serve as a basis, firstly, to carry out empirical research into the HRQOL of life of individuals over time and secondly, it will be the basis of a quantitative dynamic systems model.

The translation of the DCSM-HRQOL into a quantitative model permits to test the theoretical assumptions and to compare simulated data with empirical ones. This approach may contribute to enhance knowledge of the phenomenon under study, confirming (or not) the system structure presented here.

Conclusion

In order to analyze, understand and intervene in people's health status, reducing negative outcomes of ageing process, the construct of HRQOL was placed in a developmental perspective, following the dynamic systems theory. The conceptual model presented here could: provide new explanations about the processes acting in the ageing, generate new hypotheses and empirical questions about mechanisms and processes of changes of HRQOL during ageing, and generate new ways of measuring HRQOL, in particular in the form of repeated multivariate time serial measurements.

The general aim of the paper was to formulate the conditions and sketch the outlines of a model that enables us to study the developmental process of HRQOL in seniors. The DSCM-HRQOL employs terminology of the health definition (WHO, 1948) and the conceptualization of Testa and Simonson (1996) for the double evaluation of the inserted domains. The use of dynamic systems theory, applied to model development in old age (Schroots, 2012), seems to be a good basis to model HRQOL in the older adults, giving possible solutions and suggestions to some open questions as, in example, how HRQOL evolves during time, how the domains interact with each other, and, how life events act on HRQOL.

Future steps, starting from the conceptualization presented here, foresee the translation of the DSCM-HRQOL model in a mathematical dynamic system model that could provide additional indications about development and trends of HRQOL in the older adults population. The usefulness of a dynamic systems mathematical model can contribute to our understanding of the underlying developmental process, as previously demonstrated in the study of development in other area of research (Kunnen, 2012; Kunnen & Bosma, 2000; Steenbeek & Van Geert, 2008). The mathematical model can be used as a simulation tool (if previously validated) to analyze trends, starting from different conditions, or to simulate interventions for the maintenance/increase of HRQOL. Finally, a specific designed study is necessary to evaluate and quantify the real dynamic trend of HRQOL construct delineated here.

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