JPND SHARED

Social Health And Reserve in the Dementia patient journey

Report on the development of the first preliminary system dynamics model of factors influencing cognitive functioning in dementia

WP 5 Team

DE: Bremen, PL: Wrocław

DE: Karin Wolf-Ostermann, Imke Seifert, Henrik Wiegelmann, Maite Schlacke, Kim Westphal, Ansgar Gerhardus

PL: Marta Lenart, Mateusz Łuc, Marcin Pawłowski, Dorota Szcześniak

NL: Etienne Rouwette

WP 5 Leader: Karin Wolf-Ostermann, Joanna Rymaszewska

March 2020

Content

Background

The main aim of Work Package (WP) 5 is to develop a knowledge synthesis in the form of a system dynamics (SD) model that feeds and integrates the work and the results from WP 2, 3, 4 into a comprehensive framework of social health in conjunction with physical and mental health and its impact on cognitive decline and the course of dementia. At the end of the SHARED project this representation will be translated into elements and targets for recommendations for interventions, both for prevention and for improved dementia care.

This report aims to describe the first project phase. The focus is on the approach and first results of the preliminary system dynamics model building process (SHARED proposal: Task 5.1; Milestone 5.2; Deliverable 5.1). In this period, knowledge about cognitive functioning in dementia was systematically collected using a mixed-method approach. First of all, we conducted a systematic literature review in order to establish a solid knowledge base. The second part was a 2-day expert workshop, where the Group Model Building technique was used to expand the existing knowledge base. In a third step discussion and integration of the findings followed by a consensual discussion of the results within the team of WP 5 and among the participants of the GMB workshop. As described in the proposal, this approach aims to integrate all available information into a system dynamics representation of the multidirectional relation of social health, cognition and underlying biological substrate.

The result of this process is a first preliminary CLD model, which graphically represents the consented knowledge. This preliminary model shall feed the empirical data analysis in WPs 2-4. Furthermore, we will revise and further develop the model in an iterative way reinforcing knowledge through intermediate results from WP2-4.

Introduction

Dementia has been recognized in recent years as a global public health and social care challenge on various societal levels ranging from governments, communities, families to individuals [9, 10, 13]. There is still no cure for it and neither is there a recognized and solid prevention strategy. Although evidence already points to the fact that dementia and cognitive abilities can only be understood as multi-dimensional phenomena, the focus of preventive strategies so far has been mainly on bio-medical approaches [16].

Over the past few years the scientific discourse moved beyond unidimensional approaches, focusing on a more complex bio-psycho-social understanding of health [8, 14]. Regarding Dementia and cognitive abilities, several studies have shown that various influencing factors (risk/protective) and their interactions as well as exiting individual resources contribute to the heterogeneity observed for onset and further course of dementia [4, 6].

The variation with regard to the onset and progression of dementia indicates, that different factors can lead to differences in the pathways of cognitive abilities in individuals at different stages of life and that individuals can cope with them in different ways [18]. The recognition of these variable dynamics of cognitive decline over the life course has also become more and more attention in the academic debate and merged in the concept of the cognitive reserve [15]. The basic rationale of the thesis of the cognitive reserve are differences in the way people can respond to progressive symptoms of dementia (ebd.). Thus, individuals differ in their ability to build protective mechanisms related to lifelong cognitive skills to compensate for pathological damage acquired over the life course.[3].

How exactly these factors are related, how they interact and what effects they have on the level of cognitive reserves is not clear yet. What seems certain is that the factors are multidimensional. However, it has not yet been precisely clarified which different determinants have an impact and in which way. The basic mechanism seems to be that stimulating activities, whether physical, social or cognitive, have a positive activating effect on the neuronal capacities of the brain, thus creating protective mechanisms and compensatory potentials that reduce vulnerability to or delay the development of dementia. These stimulating activities may create buffer, cognitive reserve, against cognitive decline by enhancing brain processes. This might be protective for brain diseases like dementia, but can also compensate for occurred damages [3]. The complexity (multidimensionality, heterogeneity and dynamics) indicates the need to regard dementia and cognition abilities as complex systems consisting of more than the sum of its parts. Some studies point to the importance of social health factors to explain the cognitive reserve hypothesis, such as leisure activities, community engagement or social participation [20].

Originally the concept of social health was introduced by Huber et al. as being the dynamic balance between opportunities and limitations, shifting through life and affected by external conditions such as social and environmental challenges [21]. The concept emerged in the context of a critique of a limited understanding of health. The idea behind the concept of social health is to understand health

more holistically and above all more dynamically. Social health, as one of the three main health dimensions (besides physical and psychological health), has been conceptualized as the influence of social and environmental resources in finding a balance between one's capacities and health restrictions. Huber and colleagues further defined the concept of social health by describing it as consisting of three domains: (1) peoples' capacity to fulfil their potential and obligations, 2) the ability to manage their life with some degree of independence despite a medical condition, 3) the ability to participate in social activities including work. For the field of dementia research the concept was fruitfully applied by Vernooij-Dassen et al. as well as Droes and colleagues [22, 23, 24]. Social health is understood here, also in the SHARED project, as the 1) Competencies of the individual to participate in social life 2) the relation and interaction of the individual with the social environment and its influence on the dynamic balance between capacities and limitations [22, 23]

Based on this conceptual work on Social Health the overall aim of the SHARED project is to study the role of social health in cognitive decline and dementia, with a particular focus on their bidirectional link during the entire patient journey, the biological substrate (including imaging), and the modifying role of brain and cognitive reserve [25].

The underlying hypothesis of the SHARED project is that poor social health has a substantial influence on cognitive decline and onset of dementia. In addition, the issue is raised that accumulating brain pathology, especially during the clinical phase of the disease process, increases the need for and decreases the ability to utilize social support and care and the social integration of the person with dementia, thereby exacerbating decline in social functioning and social participation [25].

As stated above, recent studies demonstrate the role of social health factors for cognitive developments in adulthood and old age [26, 27]. In the summary of some scientific studies, having a range of good social relationships has been identified as crucial for healthy aging. These includes a lower mortality rate, better physical and mental health outcomes. Whereas social isolation may be associated with poor cognitive health. Based on the cognitive reserve theory, social isolation can lead to less mental simulation (less communication, interaction with people) which may is necessary to build cognitive reserve [28].

These explanations illustrate the potential of the social health hypothesis to contribute to further clarifying the thesis of cognitive reserve, which is the ability to actively withstand neuropathology by using compensatory cognitive approaches, i.e. over and above the risk conferred by structural and pathological features. Typical markers of cognitive reserve are educational attainment, intelligence, professional occupation, and performance on cognitive tests [29].

Nevertheless, robust data is still missing. Up to now, there is ambiguity with regard to dynamic interaction of social health and cognitive decline over life course.

Due to the fact that dementia is multifactorial, a comprehensive consideration is needed. In particular, as many factors as possible can be considered when developing prevention programs or

therapies to increase effectiveness. To be able to consider all factors, it is necessary to review them all and their interaction in promotion or prevention of dementia, which is not yet known.

As part of a European Joint Programme – Neurodegenerative Disease Research funded project Social Health And Reserve in the Dementia patient journey (SHARED), we aimed to develop such an overview that depicts the multidirectional link of social health, cognition and underlying biological substrate.

Objectives

The objectives of this first project period were a) to systematically develop an overview of causal factors in relation to the onset and progression of cognitive functioning and dementia and based on this b) to elaborate a first generic system dynamics model (as Causal Loop Diagram) visualizing how different factors of the system are interrelated.

Process flow

Figure 1 shows the process flow for the development of the preliminary CLD model. Immediately after the SHARED project started in April 2019, the WP 5 team began conducting a systematic literature review on factors impacting cognition with an emphasis on social health[1]. Although this in itself represents a separate task, it was decided to integrate the results into the development of the preliminary CLD model. In the meantime, the first GMB workshop was scheduled as a 2-day session for November 5 & 6, 2019 at Bremen University in Germany. The workshop aimed to take advantage of the expert knowledge of the interdisciplinary SHARED consortium and INTERDEM network members for creating the foundations for further model development. In the phase following the GMB, the focus was on integrating both the results of the literature review and the findings of the Dutch SHIMMY study. This step was again carried out by the WP 5 team, backed by intensive discussions and subsequent consensus. As a result, the first draft of the comprehensive Causal Loop Diagram factors influencing cognitive functioning and dementia was sent to the GMB participants for feedback. The process provisionally finished with final corrections and finalization of the preliminary model. The model was provided to WP 2-4 to support their empirical analyses.

[1] See report Lenart, Marta et al. (2019): “Report on systematic Overview of factors impacting cognition with an emphasis on social health concept”.

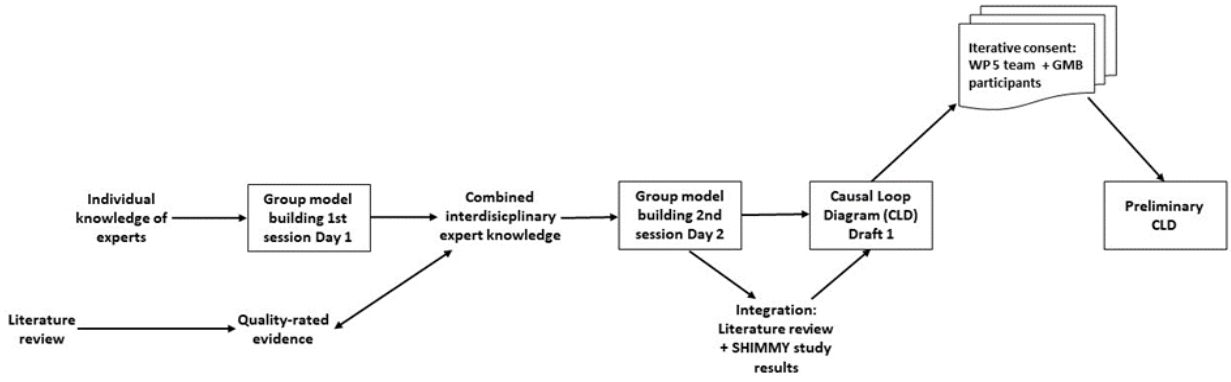


Figure 1 Process flow for the model development

First step: Literature review[2]

The objective of the literature overview was to systematically synthesize the current knowledge on factors impacting cognitive health (both positively and negatively) with a special emphasis on social health concept. It aimed to explore multidirectional relations of social health, cognition and underlying biological substrate.

The review has been conducted following PRISMA Checklist. Five online databases: Medline, PsycINFO, CINAHL Complete, Cochrane Database and Epistemonikos were searched for any type of review from 2009 to 2019. Based on eligibility criteria 458 studies were included in the systematic overview. Relevant data was extracted for each article in accordance to a predefined system of categories. The categories were developed in an iterative team approach with a final consensus decision.

Seven main categories emerged from the literature, which were later combined into six thematic clusters for further model development.[3] The category analysis clearly shows the predominance of studies on neuro-bio medical factors especially over social factors. Moreover, in the reviewed literature there is an underestimation of factors positively influencing cognition. Closer focus on social health category shows the positive impact of few reported factors (social engagement, active social participation, declared social support). Time trend of studies on social health indicates a slight increase in the number of studies reporting social health factors in the context of cognitive functions

[2] For a detailed report see Lenart, Marta et al. (2019): "Report on systematic Overview of factors impacting cognition with an emphasis on social health concept".

[3] The seven thematic categories that emerged from literature are: personal factors, socio-economic factors, lifestyle factors, social health factors, psychological factors, environmental factors and neuro-bio-medical factors.

and dementia over the last 5 years. The integrated results showing the current state of knowledge in the reviewed literature enable an overview of both - well represented and not sufficiently searched categories of factors connected with cognition and dementia.

Second step: Group Model Building

We used the Group Model Building (GMB) approach to further elaborate the knowledge base from the literature review and to start building a Causal Loop Diagram as a first comprehensive system dynamics working model. System dynamics thinking is a set of analytic methods to improve the capability of understanding complex systems and predicting their behaviours [1]. GMB is a facilitated participatory approach widely used within system dynamics [7]. It is acknowledged as an adequate way of bringing experts together in one place to exchange views on a given complex issue. The result can be a visualized consensus, i.e. a causal loop diagram [Siokou et al.].

In a GMB project, a group of stakeholders develops a model in one or more structured meetings under the guidance of a facilitator and aided by the visual display of discussion results (the conceptual model) [11]. GMB has been successfully applied since the 1970s to study a variety of (public) health issues such as chronic diseases [5]. It is particularly suitable for investigating and depicting complex public health issues (i.e. dementia) caused by a multifactorial combination of bio-psycho-social influences [2].

In November 2019, the first GMB session with an international and multidisciplinary group of researchers of the project SHARED and INTERDEM network was conducted over two days in Bremen, Germany. All participants were experts in the field of health and dementia research, therefore they were valuable in the process of developing a map of factors affecting cognitive functions using the participatory method of GMB [7].

In preparation for the SHARED GMB workshop, all participants received an information letter via Email outlining the issue under study, as well as the GMB approach and the structured process. The GMB workshop was led by an experienced GMB-facilitator (ER). He was assisted by a member of the Bremen project team, who helped to enter the data into the special System Dynamics software (Vensim) using a laptop. During the whole modelling process, the monitor of the laptop was displayed on a big screen, so that the participants could follow the process of model building. In addition, the laptop screen was recorded with OBS Classic (Open Broadcaster Software), so that the process of modelling is available for video analysis afterwards. Additionally, the session was audio recorded with the consent of the participants, in order to be able to use their arguments for/against later in the process, if necessary. The model used in this study was created using Vensim DSS, version 8.0.0 (Ventana Systems, Incorporation).

Aims of GMB workshop

The main research aims of the GMB workshop were:

a) to map relevant factors influencing dementia and cognition and to illustrate the dynamics between these factors over time;
b) to create a causal loop diagram for an integrated understanding of the role of social health in this multidimensional concept of influencing factors

GMB exercise 1: Identifying variables

The GMB session started with a welcome by the facilitator (ER) followed by an explanation of the agenda for the meeting and an indication of what the expected final product will be. The facilitator also explained the issue under study. The group started with discussing and consenting about which core variable should represent the problem issue under study. The group decided to take the term "cognitive functioning" in relation to the development of dementia.
To identify variables connected with cognitive functioning we used the Nominal Group Technique (NGT) [12], a structured method for group brainstorming that encourages contributions from everyone and facilitates quick agreement on the relative importance of issues, problems, or solutions. After three rounds, a list of variables, such as *genes, social support* or *cognitive training* were listed in Vensim. During this process, the group discussed each of these proposed variables.

GMB exercise 2: Connecting the variables

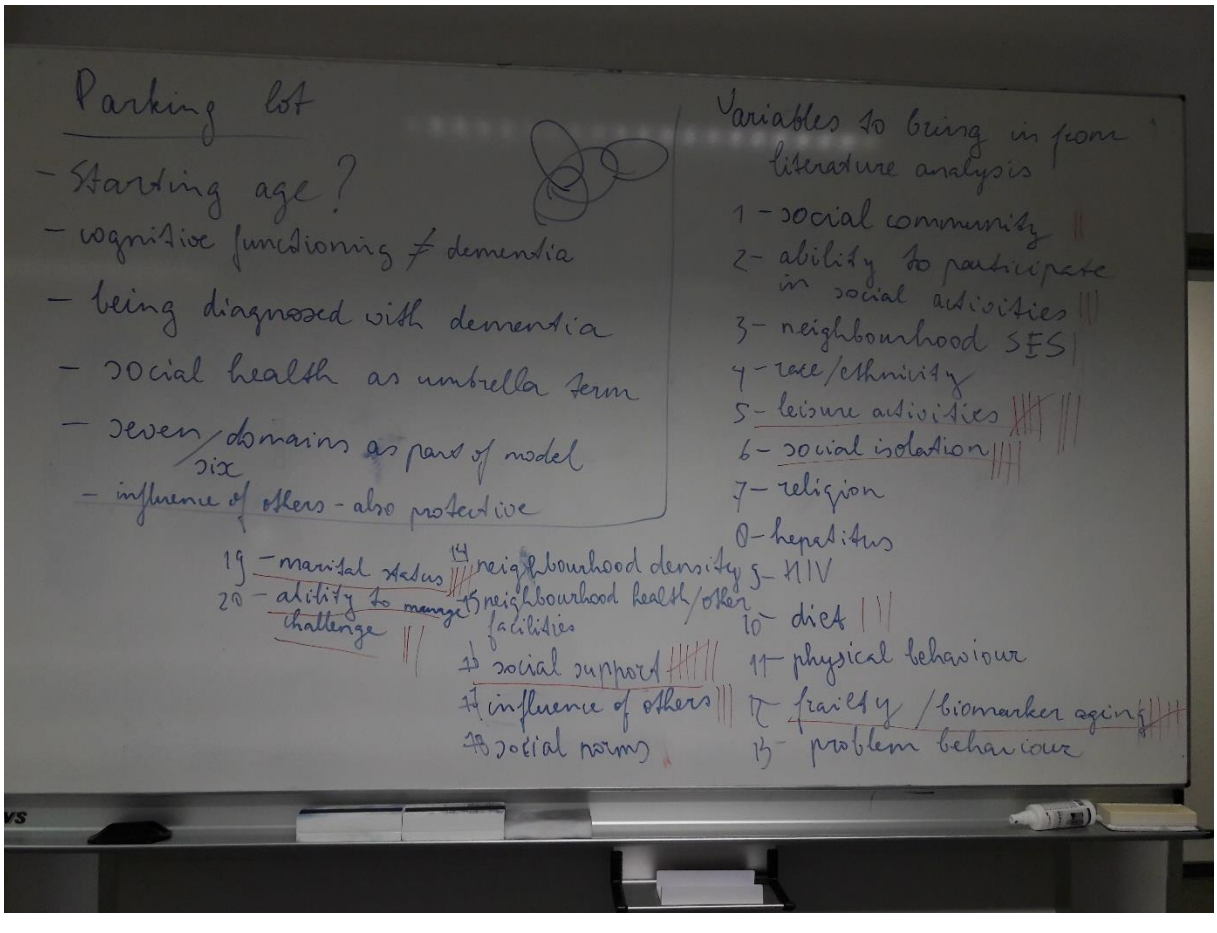
In the next step we have started to link the collected variables via sketching arrows (and polarities) to cognitive function, which was set as the centre of the model beforehand in agreement of all participants. After the proposition of the variable from each participant, the factors were gradually included into the model. In the absence of mutual agreement of all participants, an attempt was made to reach agreement in the discussion.
We provide a short explanation concerning the arrows and polarities: A connection between two factors marked positive indicates a positive relation and a connection marked negative indicates a negative relation. A positive causal link means the two factors change in the same direction, i.e. if the factor in which the link starts decreases, the other factors do that too. Similarly, if the factor in which the link starts increases, the other factor also increases. A negative causal link means the two factors change in opposite directions, i.e. if the factor in which the link starts increases, the other factor decreases and vice versa. Each arrow was discussed by the participants as a result some variables were removed. This process finished after 90 minutes.

GMB exercise 3: Integrating and modifying variables from literature review

The results of the literature review were presented to all participants and the identified variables were collated with the ones before (see GMB exercise 1 – Identifying variables).
As mentioned above, the systematic literature search was conducted in preparation for the GMB (WP 5.1) aiming to synthesize the current knowledge on factors impacting cognitive health (both positively and negatively) and affecting the development and course of dementia. These results were presented in the GMB session and the group discussed afterwards about the integration of

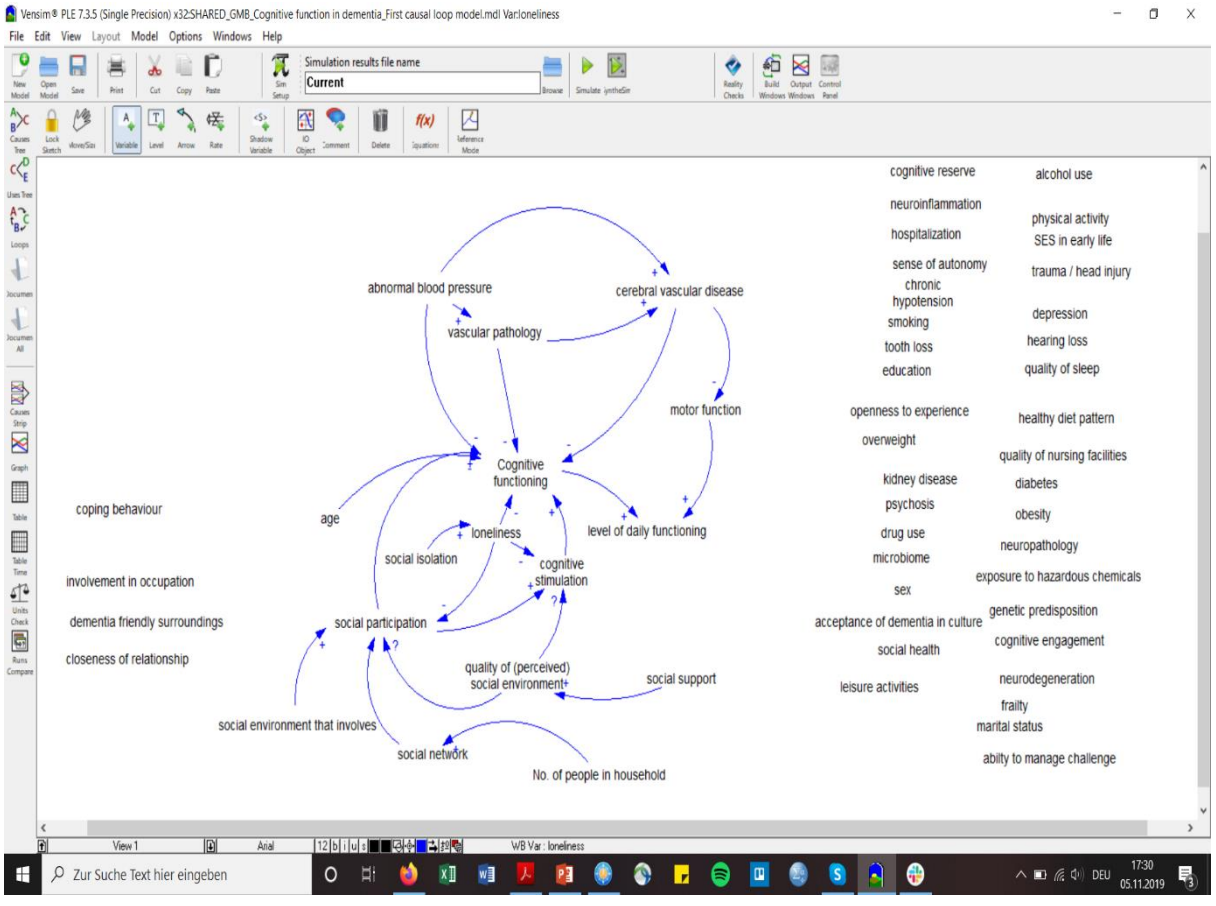
certain factors in the modelling process. Missing variables were added to the list of variables in Vensim to integrate them later on. In order to facilitate the process, each participant was supposed to name three, in his opinion, the most relevant variables. We started the process of integrating these variables with the five already chosen variables by the participants. The other variables were saved for later (see Picture 1).

Picture 1 GMB workshop - List of variables on whiteboard at 1st day



The five most frequently mentioned variables were: *leisure activity, social support, marital status, frailty/ biomarker aging* and *social isolation* (see Picture 1, right site).

Picture 2 GMB workshop - Model at the end of the 1st day



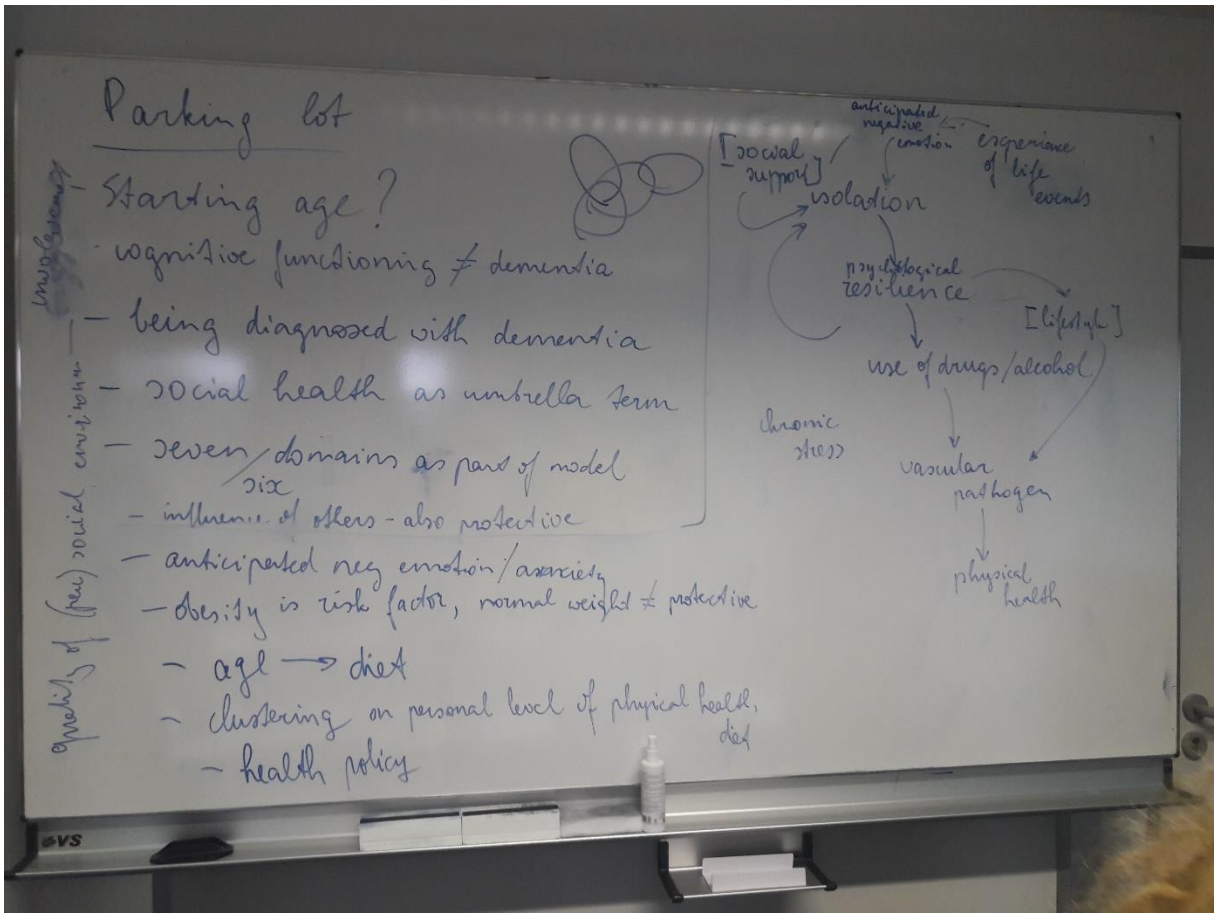
GMB exercise 4: Connecting variables and outcome

On the second day of the GMB session, the participants concentrated on linking variables to each other, discussing the relations in order to further develop the model (see Picture 3). Variables were included only with full consent of session participants. The aim was to place all (important) variables in the final GMB model (see Picture 4).

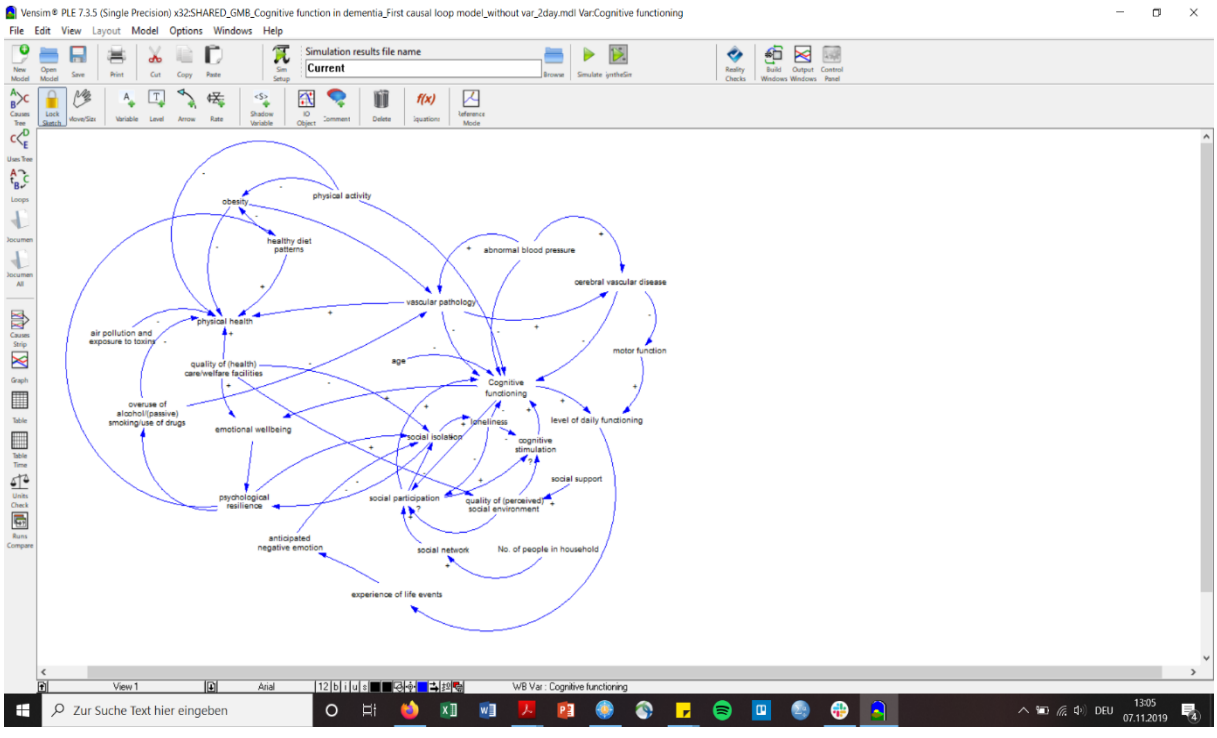
Table 1 Process steps - GMB workshop in Bremen

Source of knowledge	**Process steps**
Experts views	Exercise 1 & Exercise 2
Input from literature review	Exercise 3
Experts views	Exercise 4 & Post processing

Picture 3 GMB workshop - List of variables on whiteboard 2nd day



Picture 4 GMB workshop - Model at the end of the 2nd day



Results from the GMB workshop

GMB represents an appropriate approach (methodical brainstorming and parallel visualization) to highlight and discuss fundamental issues once again on a "blank sheet of paper" in a multidisciplinary group of experts from different points of view.

Already in the final GMB model (see Picture 4), thematic/disciplinary clusters are formed on which to further integrate the results of the literature review.

Similarly, central factors can already be found, whether in the psychological field (i.e. *resilience*), in the biomedical field (i.e. *vascular pathology*) or in the social health cluster (i.e. *social participation, loneliness, social support*).

Third step: Knowledge integration and completion of preliminary model

In the third step of model development, the results of GMB were subsequently merged with the review findings. The aim was to enrich the expert's views from the GMB workshop with evidence-based knowledge from literature. Thus, based on the state of the model at the end of the GMB workshop, further variables as well as connections and influence directions were successively added to the CLD. This step was done by close collaboration of the WP 5 research team. In some cases, variable names discussed during the GMB were replaced by variable names from the review and were appropriately modified in the merging process because they overlapped significantly in content.

After integrating all variables from the literature review, the overall arrangement of the variables and the relations between them was optimized graphically. Furthermore, we clustered the variables thematically and separated the different clusters by colour. With these steps the model's transparency has been significantly improved.

The first overall draft of the model as sent to the GMB participants for final feedback, to ask i.e. to ask, whether any variable or relation has been omitted, or any connections between variables are missing. All opinions were collected, discussed and agreed in the WP 5 team. The approved comments were finally included in the preliminary model or in the current report.

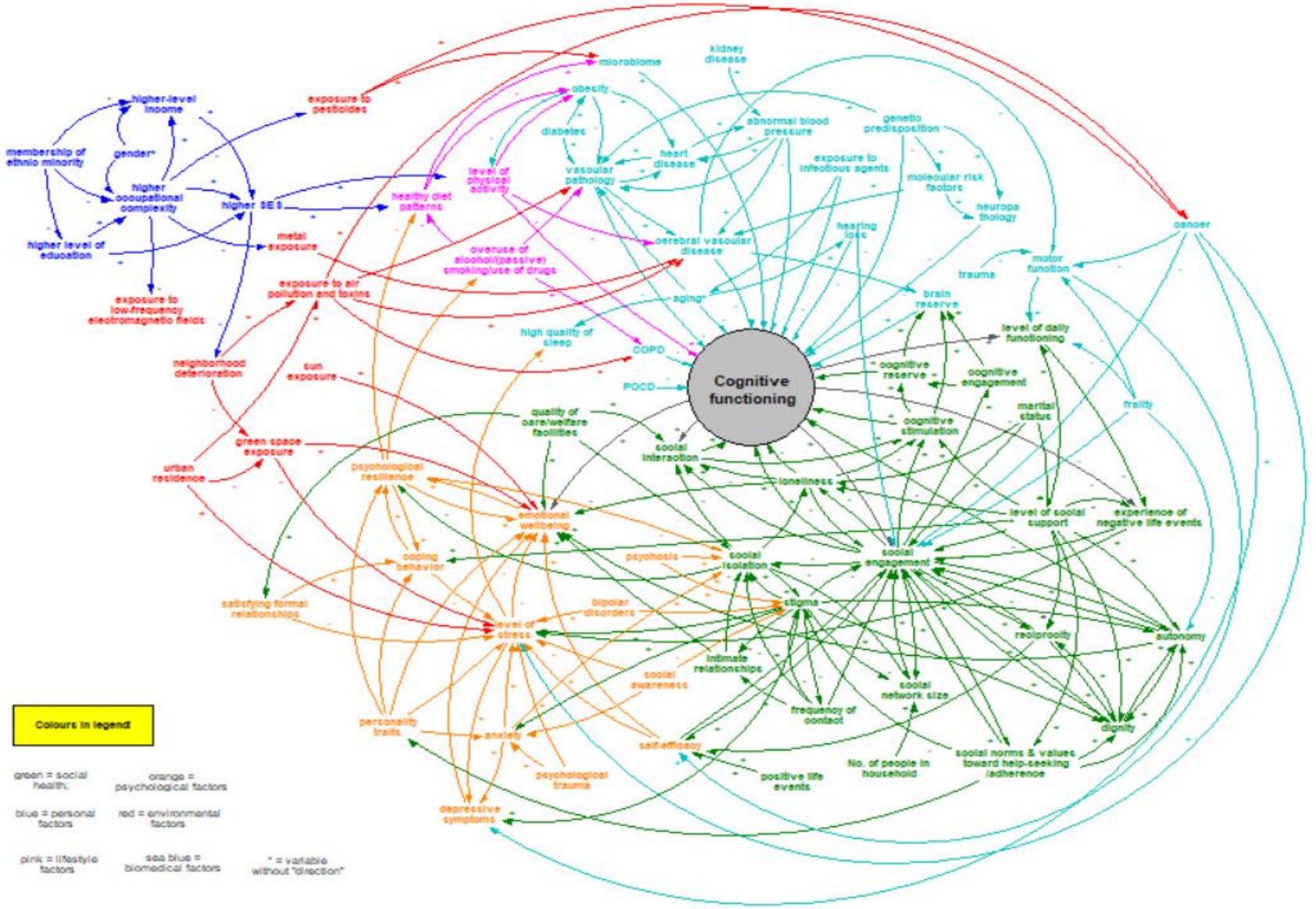
Overall results

The preliminary Causal Loop Model (CLD) is based on a) the results of the literature review, b) the results of the Group Model Building, and c) subsequent team discussions and consensus within Work Package 5, as well as feedback from consortium and INTERDEM members.

In the absence of previous compilation attempts and to map adequately the multidirectional relation of social health, cognition and underlying biological substrate, we chose wide model boundaries (i.e. physical, social, psychological, lifestyle factors and processes as well as multidisciplinary

perspectives) avoiding a deeper focus on single areas. In doing so, we pursued the goal of developing a generic and comprehensive model of factors influencing cognitive functioning. There are several high-quality review articles providing a more in-depth analysis of specific factors and interrelations. Figure 3 on the next page shows the overall CLD model in its preliminary version. On the following pages, the model will be described in more detail.

Figure 2 Overall CLD model - Preliminary version



Description of preliminary CLD

The CLD consists of variables and relations (represented as arrows) between the variables. In the centre of the model, with a grey background and larger font size, you will find the core variable "cognitive functioning". A link between two variables marked positive (a “plus” sign on the arrow/arrowhead) indicates a positive relation and a link marked negative (a “minus” sign on the arrow/arrowhead) indicates a negative relation. A positive causal link means the two variables change in the same direction, i.e. if the variable in which the link starts decreases, the other variable also decreases.[4] Similarly, if the variable in which the link starts increases, the other variable increases as well. A negative causal link means the two variables change in opposite directions, i.e. if the variable in which the link starts increases, the other variable decreases and vice versa.

The current version of the CLD – displaying the basic causal structure of the interplay of variables present in the development and trajectory of dementia - includes 73 unique factors directly or indirectly influencing cognitive functioning. The factors are grouped into six different thematic/disciplinary clusters, which were created based on literature and team discussion and were deductively approached to the datasets (literature review and group model building).[5]

Table 2 Overview - Clusters and variables of preliminary CLD

Cluster	No. of variables	Colour in CLD
Lifestyle factors	3	pink
Personal factors	6	blue
Environmental factors	8	red
Psychological factors	13	orange
Bio-medical factors	21	mint
Social (health) factors	22	green

Biomedical factors

The biomedical cluster (mint colour, top right) consists of twenty-one variables. The high number of variables in this cluster and the relatively high degree of differentiation reflects, in a way, the dominant role biomedical research has played in recent years in the dementia discourse. Within the cluster, a few key factors related to the “traffic” they generate (incoming/outgoing relations to other variables) can be highlighted. First of all, there is a *vascular pathology* factor showing intense relations, especially for causal factors (incoming relations, factors affecting *vascular pathology*). A

[4] Increasing and decreasing does not fit for each variable. For example, for the variable "marital status" the more appropriate binary distinction is available (equivalent for increase) or not available (equivalent for decrease). Studies show, for instance, that the presence of a marital relation has a positive effect on the level of social support. Available here thus functions as equivalent to increase resp. more. In other words, we can say that available is more than not-available, thus practically an increase.

[5] The clusters are based on the categories set in the process of analyzing the data of the systematic review prior the GMB. These clusters serve as structural help in the modelling process. Some variables can be assigned to more than one cluster. The clusters themselves can also be rearranged.

fundamental factor to be considered is *aging*. Although, there is no direct causal relationship between ageing and vascular pathology, it is generally recognised that the likelihood of pathology increases in the aging process. Furthermore, *obesity* and *diabetes* show relations to *vascular pathology*, both related to lifestyle factors, such as *healthy diet patterns*, *level of physical activity* or the *overuse of alcohol/(passive) smoking/use of drugs*. *Healthy diet patterns* and the *level of physical activity* are both directly influenced by the variable *higher SES* from the personal factors cluster. A number of further factors play an important role in the bio-medical cluster. Some examples are *abnormal blood pressure* and *heart disease*, both closely related to each other and also causes for *vascular pathology*. Together with the variables *abnormal blood pressure* and *cerebral vascular disease*, the factor *genetic predisposition* seems to represents an important root (outgoing relations) for directly and indirectly (via *vascular pathology*, *molecular risk factors* and *neuropathology*) influencing cognitive functioning.

Environmental factors

The environmental cluster (red colour, top left) includes eight variables. Variables of this cluster show positive causal relations to several factors from other thematic clusters, particularly to the bio-medical cluster (*cancer*, *microbiome*, *vascular pathology*, *cerebral vascular disease*, *COPD*). All of these relations are positive causal links, meaning that the existence or the increase of the respective environmental factors worsen the bio-medical health condition, which, in turn, has indirect negative effect on the core variable *cognitive functioning*. In addition to interactions with variables from the bio-medical field, there are also several links to the psychological cluster, for instance pointing on the positive influence of *sun exposure* or *green space exposure* have on *emotional wellbeing*. The latter shows also a positive link to *level of stress*, itself (*green space exposure*) again is influenced by the extent of *neighbourhood deterioration*. Besides the external relations, the environmental cluster features a number of internal connections. At this point, only few of them will be mentioned, i.e. *urban residence* leading to a decrease of *green space exposure*; an increase in *neighbourhood deterioration* leads to an increase in e*xposure to air pollution and toxins* and to a decrease of *green space exposure*. The relation between environmental factors and so-called personal factors (blue, top left) has the opposite logic. Here the question is not about the effects of an environmental factor, but about how they emerge. The cluster of personal factors covers a number of key socio-demographic/economic characteristics, demonstrating that the social situation (i.e. *higher SES*, *higher occupational complexity*) has an influence on the extent to which people are exposed to environmental toxins and that this also negatively effects cognitive health.

Lifestyle factors

The cluster of lifestyle factors (pink, top left) is the smallest of the six thematic/disciplinary fields. It consists of only three variables, placed between the socio-economic variables of the personal factors cluster and the bio-medical factors. This also illustrates an interesting pathway that relates to the question of how social aspects are linked to health, for example, when social status can lead

to health practices, which in turn can affect the increased likelihood of some somatic diseases. As already mentioned above, there are some relations between lifestyle factors and bio-medical factors, likewise in the direction of the psychological field. One variable has a direct relation to cognitive functioning: The *level of physical activity* shows a negative causal link indicating that if the *level of physical activity* decreases, then so does the probability of cognitive decline.

Psychological factors

Thirteen factors form the psychological cluster (orange, bottom left). Within the cluster there are some predominant factors causing a lot of traffic, especially on the incoming side. To highlight a few: The variables *emotional wellbeing* and *level of stress* stand out and show that many other factors from various clusters influence them. If we look closer to the variable *emotional wellbeing*, we see direct connections from the psychological (*coping behaviour*, *bipolar disorders*, *social awareness*, *self-efficacy*, *psychological trauma*, *anxiety*, *personality traits*, *satisfying formal relationships*) environmental (*green space exposure*, *urban residence*), bio-medical (*cancer*) and social (*quality of care/welfare facilities*, *loneliness*, *autonomy*, *intimate relationships*) cluster. The variable level of stress is also influenced from different fields. There are influences from other psychological factors (*coping behaviour*, *bipolar disorders*, *social awareness*, *self-efficacy*, *psychological trauma*, *anxiety*, *personality traits*, *satisfying formal relationships*).

Three other factors emerge as important nodes in the psychological field: *Psychological resilience*, *coping behaviour* and *self-efficacy*. All three of them show a number of incoming and outgoing relations to other factors. Particularly noteworthy are probably the links with the cluster of social factors. *Resilience*, for instance, has a negative causal link to *social isolation*, saying that a socially isolated person is less resilient. Besides this, *coping behaviour* is influenced positively by a higher *level of social support*. Last but not least, *self-efficacy* seems to have deep roots within the social cluster. For example, socially engaged persons show increased self-efficacy and vice versa. Furthermore, *positive life events* and *reciprocity* promote *self-efficacy*. There is also a direct link emerging from the core variable *cognitive functioning* in direction to *emotional wellbeing* indicating that a decrease in *cognitive functioning* may lead to decrease in *emotional wellbeing*.

Personal factors

There are seven factors (blue colour) grouped as personal factors in the top left part of the model. For most part, the individual relations are within the cluster. Only a few factors have links with other clusters. A central variable in the personal cluster is *higher SES*, in which the influences of education, profession and income converge. *Higher SES* on the other hand, is a root variable for some variables from the *environmental* (*exposure to pesticides*, *exposure to low-frequency magnetic fields*, *metal exposure*, *neighbourhood deterioration*) and *lifestyle* (*healthy diet patterns*, *level of physical activity*) clusters. Another variable with relations to other thematic clusters is *higher occupational complexity*. The model indicates that this variable, on the one hand, is influenced by a *higher level of education*, *gender* and *membership of ethnic minority*. On the other hand, a *higher*

occupational complexity may lead to a *higher level of income* and a *higher SES*. The model further points out, that persons who have occupations characterized by higher complexity are less exposed to environmental toxins. The basic assumption one can make for the personal factor's cluster, is that a *higher SES* protects against negative environmental influences and promotes a healthier lifestyle. This in turn has positive effects on cognitive health.

Social health factors

The social health cluster comprises a total of twenty-two social factors. Certainly, this large number, as well as the high density of relations between factors, reflect the overall issues of the SHARED project and the interest of the consortium members. In contrast, literature on social health has a relatively limited scope, as indicated by the results of the literature review. As in the other clusters, the majority of the relations are cluster-internal, much less relations exist to factors of other clusters. Only a few factors and relations can be highlighted in this report. Based on the number of relations, the variable *social engagement* - by this we understand synonymously also social participation - shows numerous root (outgoing arrows) and cause (incoming arrows) relations. All together there are sixteen variables having either a positive or a negative direct causal relation with *social engagement*. Three of them emerge from the bio-medical cluster (*hearing loss*, *cancer*, *frailty*). The core variable *cognitive functioning* has also a direct connection to social engagement, indicating a negative relation (less cognitive functioning leads to less social engagement). The variable *social engagement* for itself influences twelve other social health variables directly. Three other factors play an important role in social health: *Reciprocity*, *autonomy*, *dignity*. They all stem from the concept of social health as it was elaborated within the SHIMMY study. They are each interconnected and mutually dependent: where there is less *dignity*, there is less *reciprocity*, and where there is more *autonomy*, there is also more *dignity*, etc. Related to all three factors mentioned is the variable *level of social support* which is also an important node in the social health web, especially because it may positively influence a number of other (mostly) social health variables (*experience of negative life events*, *level of daily functioning*, *loneliness*, *coping behaviour*, *social engagement*, *reciprocity*, *social norms & values toward help-seeking/adherence*, *dignity*, *autonomy*). Starting from the variable *stigma*, further interesting relations can be identified. For instance, there is a direct relation to *social engagement*, indicating that stigmatization may have a negative influence on the level of social engagement a person can realize. Direct negative influences can also be observed in the direction of *autonomy*, *dignity*, *social network size*, *intimate relationships*, *level of stress*, *anxiety* and *social isolation*. The latter factor is of further interest because it links stigma indirectly to cognitive function via other variables. The causal cascade thesis would be here: Perceived *stigma* leads to *social isolation*, then to feeling of *loneliness*, then to less *social interaction*, then to less *cognitive stimulation* that, in the end, may lead to a decrease of *cognitive functioning*.

As already mentioned, this report cannot adequately address the complexity of the preliminary model. To address all direct and indirect relations would go beyond the scope of this document. In conclusion, however, one important pathway linking social health and cognition should be mentioned. One of the fundamental characteristics of a large number of social health factors identified in the model is that of social interaction. Social interaction refers to reciprocal actions (or influences) of factors (or groups), i.e. what happens between persons who react to each other, interact with each other and so on. Ybarra and colleagues refer in their study to the importance of social interaction and social inference for cognition:

> *"a simple exchange of views between two people requires that they pay attention to each other, maintain in memory the topic of the conversation and respective contributions, adapt to each other's perspective, infer each other's beliefs and desires, assess the situational constraints acting on them at the time, and inhibit irrelevant or inappropriate behavior."* [19]

Since the execution of those processes require a lot of attention, working memory and cognitive control (subsumed as executive functions), they stimulate cognition and may keep persons cognitively fit. We will focus on deepening our knowledge on Social Health and the relation to cognition in the next project phase, also by building on the work of Verspoor and van der Velpen [30], who propose a distinction between structural and interactional characteristics of social health. While structural characteristics relate to the infrastructure allowing interaction, examples are the existence and interconnections among social ties and roles, the interactional characteristics relate to the function of the social ties between the individual and the environment [30].

Cognitive functioning: Tree diagram analysis

During construction of a CLD and for subsequent analysis, it is worth to discover what factors are causing other factors to change. Looking in one direction, you can examine which variables cause a particular variable to change. Looking in the other direction, you can examine which variables are changed (or used) by a particular variable. The variable under study is called the "workbench variable." With the Vensim Tree Diagram analysis tool it is possible to create separate output windows showing a tree of causes branching of the workbench variable (the core variable *cognitive functioning* in this case). The Causes Tree Diagram (see Figure 3) presents the causes of a variable; the Uses Tree Diagram (see Figure 4) presents the uses of a variable.

Figure 3 on the next page shows which variables cause the *cognitive functioning* variable to change. At the very right margin of the page we find the variable under question, *cognitive functioning*. The colours of the connections correspond with the colours in the complete preliminary CLD on page 15. The same polarities as in the model (+/-) can also be found on the connections. An example is used to illustrate how the diagram should be read. For this purpose, we look at the lines at the top of the diagram. We read from left to right, following the coloured lines. There, for instance we find

the variable *obesity* in brackets. Generally speaking, *obesity* is a risk factor for *heart disease*, which in turn is a risk factor for *abnormal blood pressure*, which again in turn is a bio-medical risk factor for the decline of *cognitive functioning*. In this way the other causal traces can be interpreted. In turn, Figure 4 shows on which variables the core variable *cognitive functioning* has causal influences. For example, at the very bottom of Figure 4 it can be seen that *cognitive functioning* has a positive causal relation to *social interaction* and *social interaction* again has a positive relation to *cognitive functioning*. This represents a reinforcing negative causal loop: If cognitive functioning declines it may lead to less social interaction, which in turn may lead to further cognitive decline. These examples will help to interpret the figures on the following two pages.

Figure 3 Causes tree for core variable cognitive functioning (Four depth)

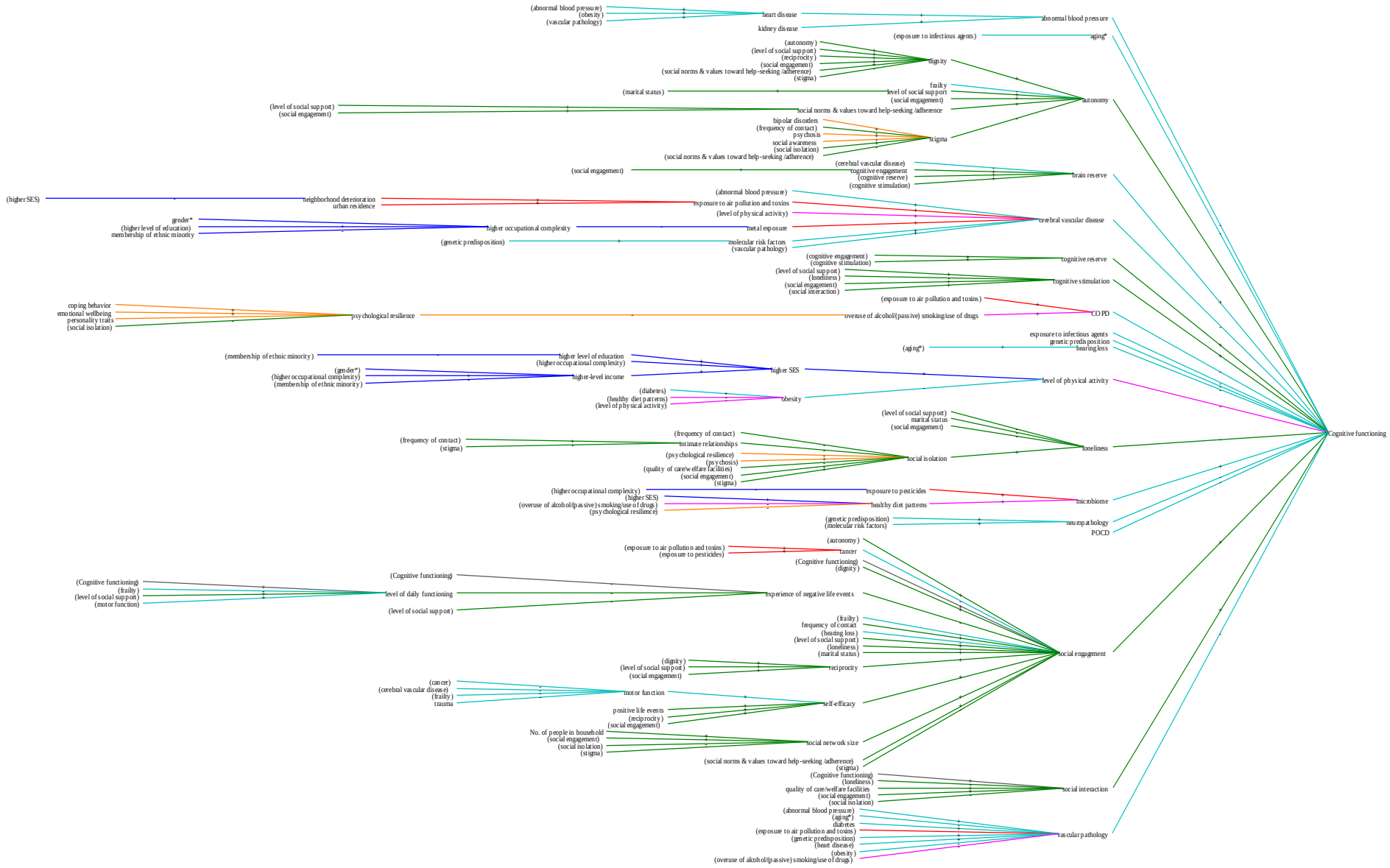
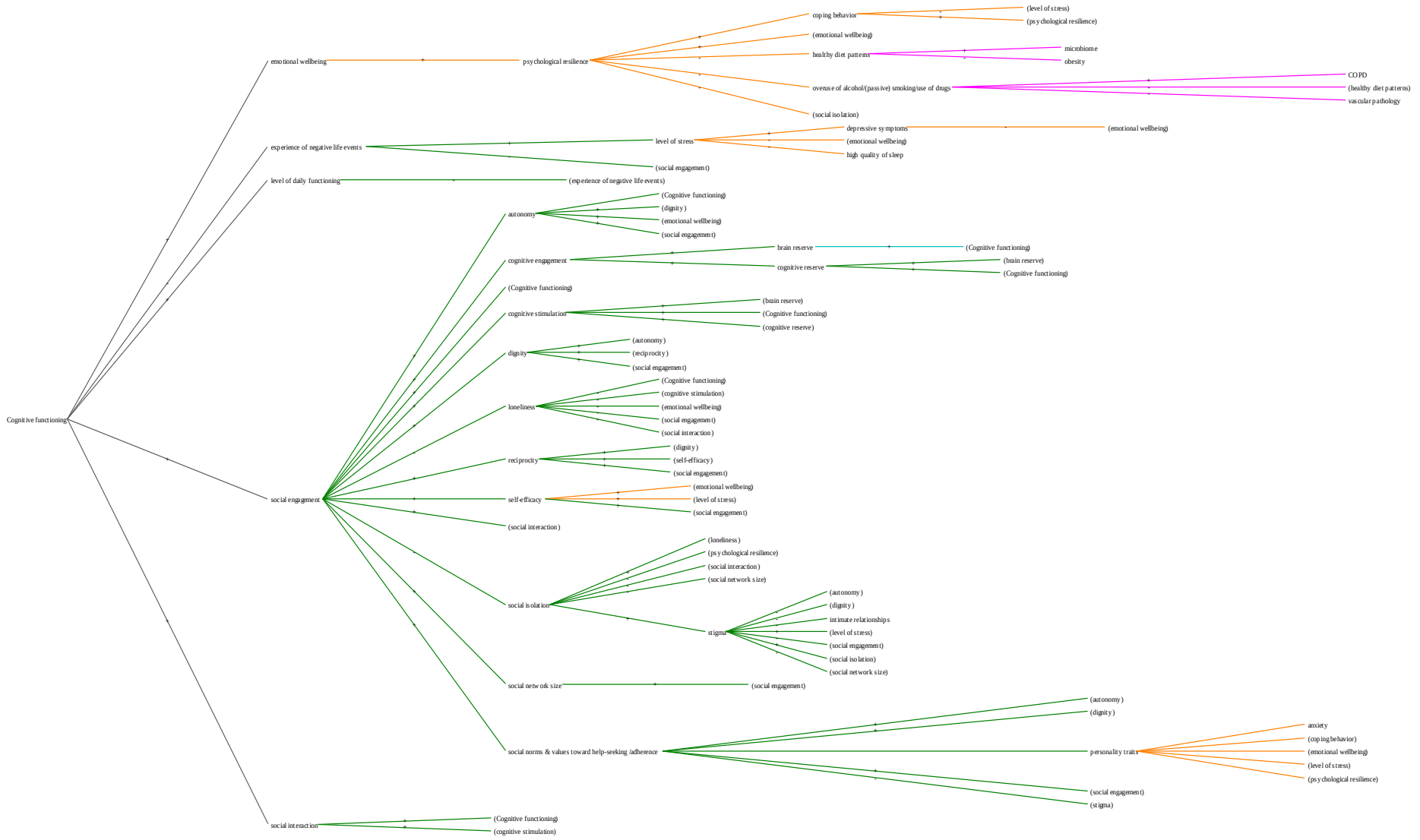


Figure 4 Uses tree for core variable cognitive functioning (Four depth)



Exemplary working hypotheses based on the preliminary model

The general hypothesis in the SHARED proposal is that social health is the driver to use cognitive reserve through active facilitation and utilization of social and environmental resources individuals and have access to. Verspoor and van der Velpen (Social health document, 14.01.2020) derive three working hypotheses from this:

1. Poor social health has a substantial influence on cognitive decline and onset of dementia.
2. Moreover, we hypothesize that poor social health exerts its effect (partly) through impacting brain reserve and cognitive reserve.
3. Finally, we hypothesize that accumulating brain pathology, especially during the clinical phase of the disease process, increases the need for and decreases the ability to utilize social support and care and the social integration of the person with dementia, thereby exacerbating decline in social functioning and social participation.

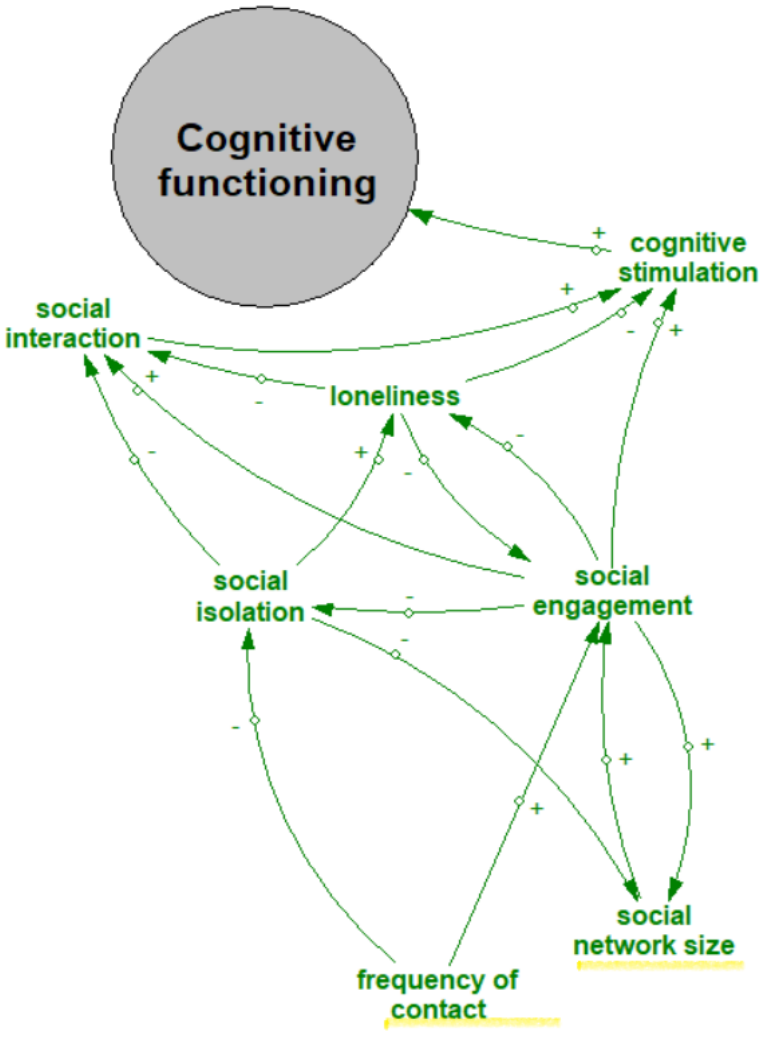
A crucial element of their social health concept is the distinction between structural characteristics and interactional characteristics of social health. The structural factors are described as the basis for the interactional factors. Depending on their characteristics, they facilitate or restrict the chances (provide access or to restrict opportunities) for social interaction and thus have an influence on social health (ebd.).

Following the conceptualization of social health, developed by Verspoor and van der Velpen and with reference to the insights from the preliminary CLD, the following working hypotheses can be drawn as examples:

H 1 Structural hypothesis: The more enabling the infrastructure (and socio-cultural circumstances) for interaction, the more intense the social interactions, the better the cognitive health.

- Structural concepts to operationalize:
    - Infrastructure: Access to resources and material goods, the social network structure, and the frequency of contact
    - Socio-cultural: Legal claims for support, cultural acceptance of dementia, quality of health care/welfare facilities

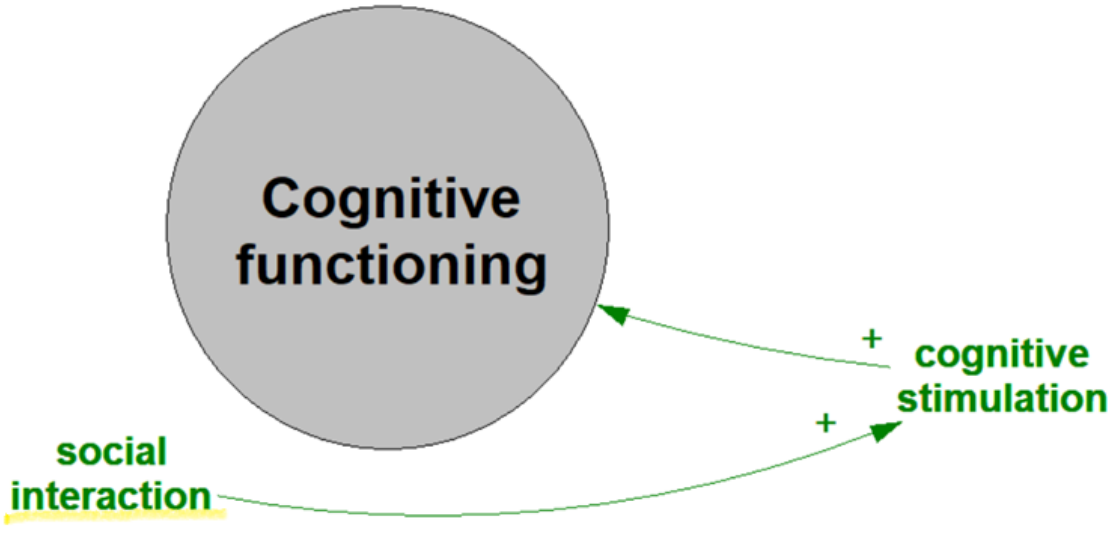
Figure 5 Structural hypothesis in preliminary CLD - Example



H 2 Interactional hypothesis: The more (meaningful) social interaction, the more cognitive stimulation, the better cognitive health/functioning.

– Social interaction can be defined by, for instance: social support, frequency of contacts, satisfaction of contacts, engagement in social leisure activities (baseline), marital status, no. of persons in household, social engagement in clubs, associations etc.

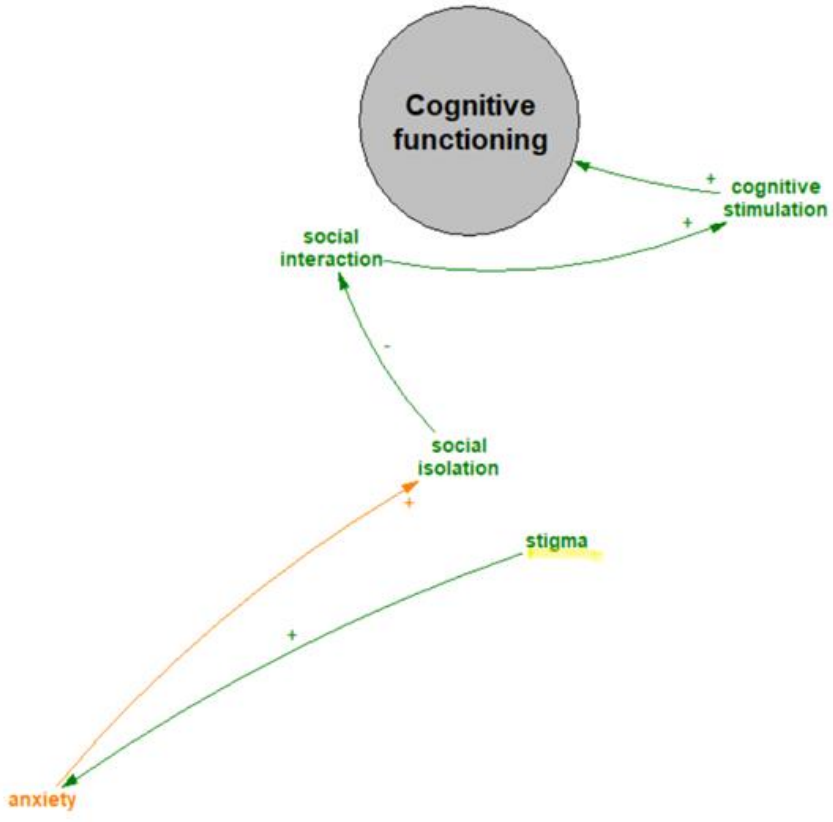
Figure 6 Social interaction hypothesis in preliminary CLD - Example



H 3 Stigma hypothesis: The more strongly the perceived stigmatization (person with dementia or proxy), the more mental problems (i.e. anxiety, depression, self-esteem), the less social interaction, the less cognitive stimulation through social interference, the poorer cognitive functioning/health.

– Perceived stigmatization (i.e. social rejection, social isolation, internalized shame) can be measured by the Stigma Impact Scale (SIS) or similar instruments

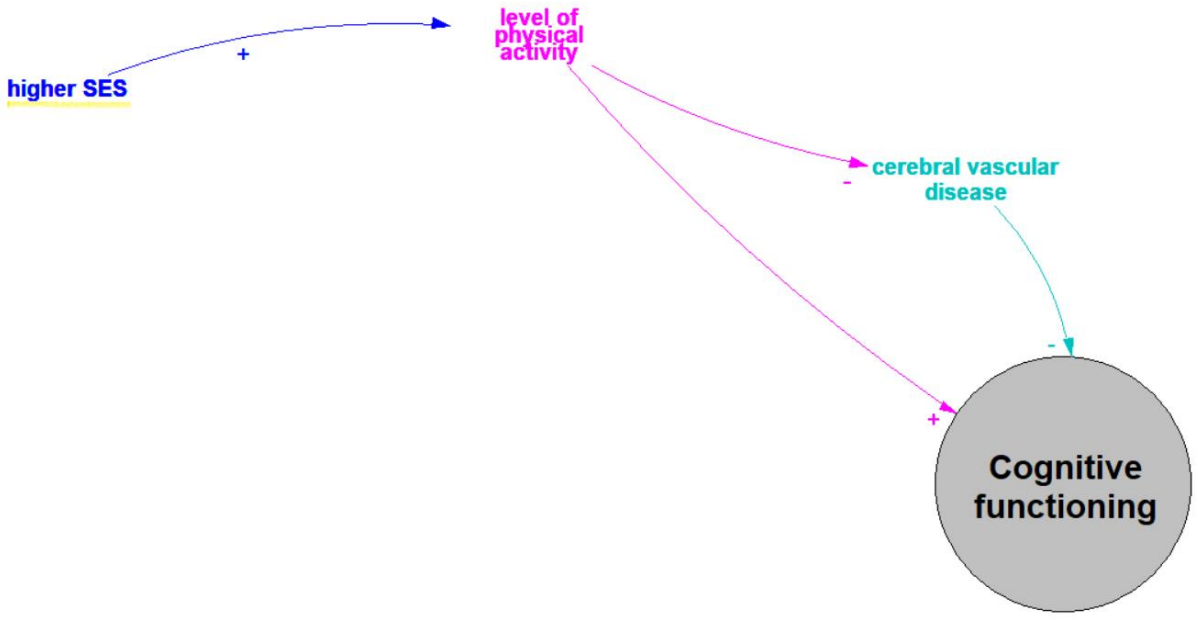
Figure 7 Stigma hypothesis in preliminary CLD - Example



H 4 Social inequality hypothesis: The more socially privileged (higher social status) a person, the healthier lifestyle, the better physical health, the better cognitive functioning

- Social status can be defined by, for instance: Socio-economic status, level of occupational complexity, level of education, level of income
- Lifestyle can be measured by, for instance: level of physical activity, diet patterns, use of alcohol, (passive) smoking, use of drugs
- Physical health can be measured by, for instance: vascular pathologies, cerebral vascular disease

Figure 8 Social inequality hypothesis in preliminary CLD - Example



These are examples of some of the causal hypotheses that can be formed using the preliminary model. In this way, linking variables using positive and/or negative relations, further hypotheses can be formed.

Conclusion

The preliminary CLD reflects the knowledge of a multidisciplinary group of researchers from the SHARED consortium and INTERDEM network, merged with results from a systematic literature overview and supplemented by discussion and iterative feedback from the WP5 team as well as the SHARED consortium.

The mix of applied methods as well as the visualization using CLD with Vensim Software has turned out to be a reasonable approach to develop and graphically represent the complex structure of factors influencing cognitive functioning in dementia.

Furthermore, the understanding of the development of cognitive functioning in dementia has been discussed effectively with the GMB, integrating perspectives from various disciplines. However, even if we had the ambition to visualize the interplay of social health factors and the influences of all relevant factors on the development of cognitive functioning and dementia, the developed model simplifies reality for greater understanding. Despite this, we can outline few strengths of the used technics.

A strength of the model is that it was developed by a multidisciplinary group of researchers, and thus several perspectives have been integrated its construction.

Another advantage is that the results of systematically searched literature are also included. In addition, the model is distinguished by a clear presentation of factors affecting dementia and their interactions.

Additionally, the authors are aware that a CLD like this can be developed on different levels of abstraction. For example, some variables can be split up into more detailed variables (lower level of abstraction) or variables can be merged (higher level of abstraction). The current preliminary model has no uniform level of abstraction. While individual variables (i.e. *marital status*) are already at a measurable level, others are more abstract in nature (i.e. *autonomy*), which would require further operationalisation as measuring instruments.

Furthermore, the aim was to develop a generic model. This is accompanied by the fact that a model like this cannot address every individual situation. Rather, the model reflects a fairly "general standard case".

Last not least: Many relations are inside the clusters, but less between the clusters. However, this is where interesting questions arise, also for the SHARED project, namely those that focus on the multidimensional view of cognitive functioning and both positive and negative influences as well as the reciprocal relation between social health and cognition.

However, the critical aspects should be seen in the light of the fact that this is the first working model, a preliminary CLD. This will be further developed in a structured way in the course of the SHARED project.

Even though social health is gaining increasing scientific attention, the mechanisms and interrelationships have not yet been clearly studied. The model gives a first comprehensive visualisation highlighting interactions within the social health cluster as well as between SH cluster and other clusters, having an impact on cognitive functioning. As our preliminary model (see Figure 2) demonstrates, social health plays a crucial role in the prevention and treatment of people with dementia, which is why it should be given importance in the research it deserves. We will focus on deepening the knowledge on social health and the relation to cognition and biological substrate in the next project phase, incorporating results from Work Packages 2-4 into the model development.

Outlook

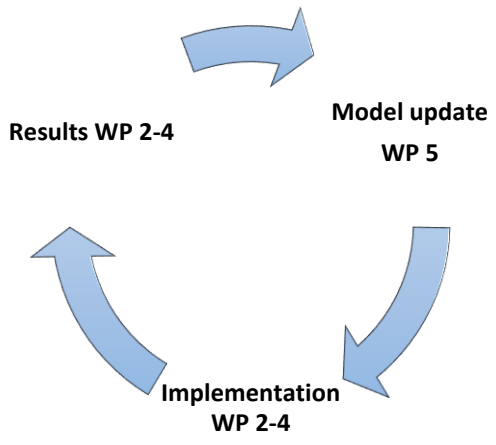
As described in the SHARED proposal the next task is to fulfil Milestone 5.2 and deliverable 5.1. To achieve this, we will develop a concept for a staged approach for model development, meaning that the model will be revised at defined steps in the project. It is also the aim to deliver the basis for building hypotheses for the other WPs.

Task 5.2 and also Milestone 5.3 requires us to agree on and develop a structured way to revise and further develop the model in an iterative way reinforcing knowledge through intermediate results from WP2-4. Therefore, we need to create procedures for continuous knowledge exchange by

virtual and personal meetings and model elaboration will we developed (milestone 5.3). To meet these objectives and build on the work done so far, we propose the following procedure:

1. **Step:** Pruning the model by implementing a three level system. This means that we develop three model layers, one each on the micro, meso and macro level. At the macro level, the model will represent only key dimensions of cognitive functioning (i.e. physical factors, psychological factors, social factors). The meso level will consist of the most important concepts/constructs within those key dimensions (i.e. for social factors concepts like social engagement, loneliness, social support). On the micro level we have the opportunity to further elaborate the detailed model developed so far.
2. **Step:** Transfer of the knowledge base developed so far from Vensim to Kumu Inc (https://kumu.io/). Kumu offers additionally tools for developing the model and it is graphically more appealing. It provides, for instance, the possibility to fill individual factors or links of the model with knowledge elements (literature, measuring instruments, etc.). Thus we would be able to further develop the model into a knowledge database. In view of the planned activities of the SHARED Social Health Stream to develop a Toolkit on Social Health, synergies can be created.
3. **Step:** We will develop a simple reporting form and forward this to WP 2-4. This form is meant to enable the structured feedback of results of the empirical studies conducted.
4. **Step:** The results of the studies from WP 2-4 will be integrated iteratively into the model. This process (see Figure 9) is ongoing.

Figure 9 Iterative development of CLD – Simplified illustration



Meeting in Wroclaw April 2020 (cancelled due to COVID-19)

We would like to discuss the function, progress and further development of the preliminary model during the project meeting in Wroclaw in April (1-2h) and then adapt the process accordingly.

Deepening the Social Health focus

In the next project phase, we will focus on deepening our knowledge on Social Health and the relation to cognition. As discussed within the Social Health Group, WP 5 in close cooperation with the other partners from WP 2-4 will push this forward by building on the results of the Dutch SHIMMY study to create a toolkit on how to measure Social Health.

References

1. Arnold RD, Wade JP (2015) A definition of systems thinking: A systems approach. Procedia Computer Science 44:669-678
2. Craig J (2008) Complex diseases: research and applications. Nature Education 1
3. Evans IE, Llewellyn DJ, Matthews FE et al. (2018) Social isolation, cognitive reserve, and cognition in healthy older people. PloS one 13:e0201008
4. Hersi M, Irvine B, Gupta P et al. (2017) Risk factors associated with the onset and progression of Alzheimer's disease: a systematic review of the evidence. Neurotoxicology 61:143-187
5. Homer J, Milstein B, Wile K et al. (2008) Modeling the local dynamics of cardiovascular health: risk factors, context, and capacity. Prev Chronic Dis 5:A63-A63
6. Hou X-H, Feng L, Zhang C et al. (2019) Models for predicting risk of dementia: a systematic review. J Neurol Neurosurg Psychiatry 90:373-379
7. Hovmand PS, Andersen DF, Rouwette E et al. (2012) Group Model-Building 'Scripts' as a Collaborative Planning Tool. Systems Research and Behavioral Science 29:179-193
8. Huber M, Knottnerus JA, Green L et al. (2011) How should we define health? Bmj 343:d4163
9. Livingston G, Sommerlad A, Orgeta V et al. (2017) Dementia prevention, intervention, and care. The Lancet 390:2673-2734
10. Organization WH (2017) Global action plan on the public health response to dementia 2017–2025. In:World Health Organization, Geneva
11. Rouwette EaJA, Vennix JaM, Thijssen CM (2000) Group Model Building: A Decision Room Approach. Simulation & Gaming 31:359-379
12. Sample JA (1984) Nominal group technique: An alternative to brainstorming. Journal of Extension 22:1-2
13. Shah H, Albanese E, Duggan C et al. (2016) Research priorities to reduce the global burden of dementia by 2025. The Lancet Neurology 15:1285-1294
14. Spector A, Orrell M (2010) Using a biopsychosocial model of dementia as a tool to guide clinical practice. International Psychogeriatrics 22:957-965
15. Stern Y (2012) Cognitive reserve in ageing and Alzheimer's disease. The Lancet Neurology 11:1006-1012
16. Van Der Linden M (2016) Juillerat Van der Linden AC. A life-course and multifactorial approach to Alzheimer's disease: Implications for research clinical assessment and intervention practices. Dementia:1-16
17. Winblad B, Amouyel P, Andrieu S et al. (2016) Defeating Alzheimer's disease and other dementias: a priority for European science and society. The Lancet Neurology 15:455-532
18. Zahodne LB, Schupf N, Brickman AM et al. (2016) Dementia risk and protective factors differ in the context of memory trajectory groups. Journal of Alzheimer's Disease 52:1013-1020
19. Ybarra O, Burnstein E, Winkielman P et al. (2008) Mental exercising through simple socializing: Social interaction promotes general cognitive functioning. Personality and social psychology bulletin. Vol. 34 No. 2, February 2008 248-259
20. Fratiglioni L, Paillard-Borg S, Winblad B (2004): An active and socially integrated lifestyle in late life might protect against dementia. The Lancet Neurology. 3(6), 343-53.
21. Huber M, Knottnerus JA, Green L, et al. (2011). How should we define health? BMJ 2011; 343: d4163.
22. Vernooij-Dassen M, & Jeon YH (2016). Social health and dementia: The power of human capabilities. International Psychogeriatrics, 28(5), 701–703.
23. Vernooij-Dassen M, Moniz-Cook E, Verhey F, Chattat R, Woods B, Meiland F, Franco M, Holmerova I, Orrel M, de Vugt M (2019). Bridging the divide between biomedical and psychosocial approaches in dementia research: the 2019 INTERDEM manifesto. Aging & Mental Health. DOI: 10.1080/13607863.2019.169.

24. Droes RM, Chattat R, Diaz A, Gove D, Graff M, Murphy K, et al. (2017). Social health and dementia: a European consensus on the operationalization of the concept and directions for research and practice. Aging and Mental Health; 21: 4–17.
25. Ikram A, Melis R, Perry M, Vernooij-Dassen M, Welmer AK, Hui-Xin W... Jeon JH (2019). Social health and reserve in the dementia patient journey (SHARED). In: European Joint ProgrammeNeurodegenerative Diseases (JPND).
26. Bennett DA, Schneider JA, Tang Y, Arnold SE, Wilson RS (2006. The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: a longitudinal cohort study. The Lancet Neurology. 5: 406-12.
27. Kuiper JS, Zuidersma M, Zuidema SU, Burgerhof JG, Stolk RP, Voshaar RCO … (2016). Social relationships and cognitive decline: a systematic review and meta-analysis of longitudinal cohort studies. International Journal of Epidemiology. 2016: dyw089.
28. Evans IEM, Llewellyn DJ, Matthews FE, Woods RT, Brayne C, Clare L (2018). Social isolation, cognitive reserve, and cognition in healthy older people. PLoS ONE. 2018;13: e0201008.
29. Stern Y. What is cognitive reserve? Theory and research application of the reserve concept (2002). Journal of the International Neuropsychological Society 2002; 8: 448–460.
30. Verspoor E, van der Velpen I (2020). Social health and cognitive functioning. Unpublished manuscript.

Annex 1: List of model variables with clusters

Variable (construct)	**Cluster**
Higher-level income	Personal factors
Membership of ethnic minority	Personal factors
Gender	Personal factors
Higher level of Education	Personal factors
Higher occupational complexity	Personal factors
Higher SES	Personal factors
Exposure to pesticides	Environmental factors
Exposure to low-frequency electromagnetic fields	Environmental factors
Metal exposure	Environmental factors
Exposure to air pollutions and toxins	Environmental factors
Neighborhood deterioration	Environmental factors
Sun expose	Environmental factors
Green space exposure	Environmental factors
Urban residence	Environmental factors
Healthy diet patterns	Lifestyle factors
Level of physical activity	Lifestyle factors
Overuse of alcohol/(passive) smoking/use of drugs	Lifestyle factors
Microbiome	Bio-medical factors
Obesity	Bio-medical factors
Kidney disease	Bio-medical factors
Vascular pathology	Bio-medical factors
Hear disease	Bio-medical factors
Cerebral vascular disease	Bio-medical factors
Aging	Bio-medical factors
COPD	Bio-medical factors
POCD	Bio-medical factors
High quality of sleep	Bio-medical factors
Abnormal blood pressure	Bio-medical factors
Exposure to infectious agents	Bio-medical factors
Hearing loss	Bio-medical factors
Genetic predisposition	Bio-medical factors
Molecular risk factors	Bio-medical factors

Neuropathology	Bio-medical factors
Motor function	Bio-medical factors
Trauma	Bio-medical factors
Brain reserve	Bio-medical factors
Cancer	Bio-medical factors
Frailty	Bio-medical factors
Psychological resilience	Psychological factors
Satisfying formal relationships	Psychological factors
Personality traits	Psychological factors
Coping behavior	Psychological factors
Level of stress	Psychological factors
Depressive symptoms	Psychological factors
Anxiety	Psychological factors
Psychological trauma	Psychological factors
Social awareness	Psychological factors
Bipolar disorders	Psychological factors
Psychosis	Psychological factors
Self-efficacy	Psychological factors
Emotional wellbeing	Psychological factors
Quality of care/welfare facilities	Social (health) factors
Social interaction	Social (health) factors
Loneliness	Social (health) factors
Social isolation	Social (health) factors
Stigma	Social (health) factors
Intimate relationships	Social (health) factors
Frequency of contact	Social (health) factors
Positive life events	Social (health) factors
No. of people in household	Social (health) factors
Social networks size	Social (health) factors
Social engagement	Social (health) factors
Social norms & values toward help-seeking/adherence	Social (health) factors
Reciprocity	Social (health) factors
Dignity	Social (health) factors
Autonomy	Social (health) factors
Level of social support	Social (health) factors
Experience of negative life events	Social (health) factors

Marital status	Social (health) factors
Cognitive stimulation	Social (health) factors
Cognitive engagement	Social (health) factors
Cognitive reserve	Social (health) factors
Level of daily functioning	Social (health) factors

Table 3 List of model variables with clusters