6. Social behavior and cognitive monitoring in healthy aging

C. Röcke[1]*, S. Guye[1], M. Girolami[2], I. Kniestedt[3]

[1] University of Zurich, University Research Priority Program "Dynamics of Healthy Aging", Zurich, Switzerland

[2] National Council of Research, ISTI-CNR, Pisa, Italy

[3] Technical University Delft, Netherlands

Abstract Social integration is a key predictor of health in later life, as is cognitive functioning. This chapter describes the evidence related to levels of and interventions on social integration and cognitive functioning for older adults and outlines how this evidence was translated into the personalized coaching approach in NESTORE in both of these domains. From the technological side, social beacons are used to obtain objective contact measures for users' local social networks and thus complement self-report information on social interactions beyond face-to-face contacts. In the cognitive domain, a serious game involving a multidomain cognitive training was developed on the basis of evidence-based game and training principles.

***Corresponding author**
Christina Röcke
University of Zurich
University Research Priority Program "Dynamics of Healthy Aging
Andreasstrasse 15, Box 2
CH-8050 Zurich
Switzerland
Phone: +41 44 635 7495
christina.roecke@uzh.ch

6.1 Introduction

Social participation, that is having a social network of close others available to draw upon in good and bad times represents a strong correlator and predictor of physical and mental health as well as survival (Dahan-Oliel, Gélinas, & Mazer, 2008; House, Landis, & Umberson, 1988; Seeman, 1996).

The social networks of older adults tend to be overall smaller than during midlife and young adulthood, but the number of emotionally close other persons remains fairly stable until old age on average (Fung et al., 2001, 2008) and the availability of social support also tends to be maintained (Ertel et al., 2009). Consistent with the notion that emotionally close others remain available in the networks from young up to old age, certain social relationship types show greater changes than others. For instance, the family network shows stability from adolescence/young adulthood to old age, whereas the friendship and personal network show decreases into old age and networks with co-workers or neighbours play an important role only in defined periods during the life span (Wrzus et al., 2013). Social and emotional functioning shows reliable interplay. Older adults tend to report greater satisfaction with their networks than younger adults (Carstensen, 1992) and they report fewer negative social interactions than their younger counterparts (Birditt & Fingerman, 2003).

With the rise of experience sampling and ambulatory assessment methods and designs in psychological research, including lifespan developmental and ageing research (e.g., Brose & Ebner-Priemer, 2015; Hoppmann & Riediger, 2009; Trull & Ebner-Priemer, 2013), there have been novel ways of examining social integration more in terms of a behaviour and fluctuating experience and not only as a stable person characteristic and over long-term time spans using survey questionnaires that tap the general/typical or retrospective status of the social network and social support exchanges as well as leisure activities including those that involve social interactions (e.g., Jopp & Herzog, 2011). Much of this research is conducted in young adult samples (e.g., Gable, Gosnell, & Prok, 2012; Hoppmann & Riediger, 2009). Older adults have been shown to report fewer interpersonal stressors than middle-aged and younger adults and also that they felt less stressed in reaction to the tensions that occurred than young adults (Birditt et al., 2005; Charles et al., 2009). Older adults, compared to younger age groups, have also been found to report more interpersonal tensions with spouses than with children, unlike younger age-groups which may be due to the fact that older adults' children have likely moved out from home and even further away, so there is less room for tension. In line with the expectation that lifelong experience in dealing with emotional situations, older adults have also been found to show more passive constructive (e.g., do noting) behaviour in response to tensions than middle-aged and younger adults, and less arguing than the younger adults (Birditt et al., 2005).

Many interventions in the social domain do not target older adults (Ertel et al., 2009). Of those that do explicitly have the older population in mind, many have a strong focus on decreasing or preventing loneliness and aim on improving social skills, enhancing social support, increasing opportunities for social interaction and social cognitive training (Masi et al., 2011). These target domains reflect theoretical models of loneliness that propose an individual difference concept such that lonely and non-lonely individuals approach and appraise social encounters differently, including more sceptical and negative perceptions of and during interactions and behaviours that are more likely to lead to rejection on the side of the lonely persons (cf. Masi et al., 2011). Many loneliness interventions thus intend to increase the quantity and quality of relationships. To date, there is mixed evidence on the success of social network interventions in later life (e.g., Findlay, 2003). The general coaching approach in the social well-being domain in NESTORE is described in more detail in Chapter 2.

Cognition is among the most widely studied domains in the ageing literature. Despite the possible stereotype and assumption of prevailing losses, cognitive functioning does not show uniform decline as people age. Much in line with lifespan theoretical notion of multidirectional development (Baltes et al.., 1999), two components of cognitive functioning can be differentiated and show distinct trajectories of age-related change: whereas fluid abilities such as processing speed and working memory tend to decline with increasing age, crystallized abilities such as vocabulary, knowledge, and autobiographical memory tend to increase or be maintained (Hedden & Gabrieli, 2004; Salthouse, 2010). Overall, in addition to the broad distinction between fluid and crystallized cognitive abilities, there is quite some complexity and heterogeneity in trajectories of stability and change across cognitive domains (Hartshorne & Germine, 2015).

In NESTORE, we assessed status and daily life performance in the social and cognitive domains using standard instruments and employed coaching in both of these domains with evidence-based structured and unstructured tasks.

6.2 Monitoring of Social Behaviour in NESTORE

6.2.1 Self-Reported Social Integration and Behaviour

In NESTORE, the social status and behavior of the users are assessed both at baseline and posttest, as well as in daily life during the coaching phase, using various standard questionnaires that focus on measuring social and emotional loneliness and the degree of social integration with family and friends. Furthermore, we assess received and provided social support as an additional outcome variable related to social well-being. Table 1 provides and overview of the social network constructs assessed within NESTORE and the respective measurement instruments.

Table 1. Self-Report Social Monitoring Variables and Instruments

Construct	Measurement Instrument
Social Well-Being Status (Baseline, Posttest)	
Loneliness	De Jong Gierveld Loneliness Scale
Social Integration with Family and Friends	Lubben Social Network Scale 6
Perceived Social Support	Berlin Social Support Scales
Social Well-Being in Daily Life	
Social Interactions (Frequency, Type)	Single Items from Experience Sampling Literature
Social and Emotional Loneliness	Single Items from De Jong Gierveld Loneliness Scale

6.2.2. Sensor-Based Social Behavior Assessments

Understanding the way people interact raises a number of challenges. As reported in the previous section, the NESTORE project implements self-report tools for the social integration with the goal of collecting subjective feedbacks from the end-users during the pilot sites. This approach is undoubtful a first required step for a better comprehension of the social attitude of people, while following the NESTORE pathways. The data collected can provide a first outlook of the amount and of the quality of the social interactions. However, such approach can be complemented with a second method based on the objective measurement of the features characterizing of the social context. To this end, we describe the monitoring and analytics tools designed for monitoring interactions among subjects involved in the NESTORE pilot sites with sensing-based devices.

The pervasive diffusion of mobile sensing technologies opens to a new era for experiments and initiatives devoted to revealing the ties binding people. A tie between two individuals is the result of several factors combined together, such as the time spent in proximity, emotional intensity, use of gestures and verbal communication (Granovetter, 1983); such factors ultimately determine the strength of a tie (Marsden & Campbell, 1984). The NESTORE project focuses on one of such sociological markers, namely proximity, as a necessary condition for a face-to-face social interaction. Determining the proximity between two or more individuals refers to the possibility of detecting, with sensing technologies, those users who are nearby. As originally proposed by Edwad T. Hall in 1963 with the term proxemics, interactions among people, generally, happen in the so-called social space, a virtual radius surrounding us ranging from 1 to 3.5 meters approximately. Of course, such range can vary according to numerous factors: obstacles, crowded environments, personal attitude etc. nevertheless we argue that it represents a reference distance to be considered for detecting people in the nearby.

Proximity can be detected by assuming that a personal device, e.g., a smartphone, smartwatch or a tag, acts as proxy for the person. More specifically, we aim at detecting the proximity between user's devices with proximity-based sensing technologies. To this purpose, we adopted the Bluetooth Low Energy technology as a cheap and effective solution for the identification of devices at a given distance. We briefly report the main features of the NESTORE kit adopted for the proximity detection, we refer to Chapter [REF TO PROPER CHAPTER] and to (Palumbo et al., 2020) for an in-depth description of the hardware design. The kit is composed by two elements: a receiver and an emitter, as reported in Figure 1. The receiver is the NESTORE wristband [REF TO PROPER CHAPTER] able to receive, store and upload short messages broadcasted by the emitting devices. The emitter is a Bluetooth tag that periodically propagates messages with a given advertisement rate and at a given power of emission. Since the emitter is configured to broadcast messages at a given power, the receiver can listen for such messages only at a given distance from the emitter. As a result, messages are recorded only from devices at a given proximity. The receiver stores some information about the messages it receives, the timestamp, the id of the message and the received signal strength indicator (RSSI) as a measurement of the quality of the messages. The higher the RSSI, the closer the emitting device. The relationship between RSSI and distance holds in outdoor environments under a specific condition (Barsocchi, Oligeri, & Potorti, 2009): without the presence of obstacles in-between the emitter and the receiver and without any kind of wireless interferences. Differently, in indoor environments, the strength-distance relationship might not hold because obstacles, multi-path fading, interferences and human bodies can alter the quality of the signals (Baronti, Girolami, Mavilia, Palumbo & Luisetto, 2020). Both the emitter and the receiver have been designed to operate continuously without the explicit user intervention.

The emitter devices are assigned only to the primary NESTORE users, namely the individuals recruited according to the selection criteria defined for the purpose of the pilot studies. The NESTORE user is required to wear the NESTORE wristband all day and to recharge it periodically. The receiving devices are assigned to the user's local circle, namely a set of 5 people (friends/relatives/caregivers/neighbours) identified by every NESTORE user (see Figure 1). The members of the local circle are required to bring the emitter devices every time she/he visits the NESTORE user. To serve this purpose the emitter device is a simple tag that can be locked to the key-ring or put in the pocket.

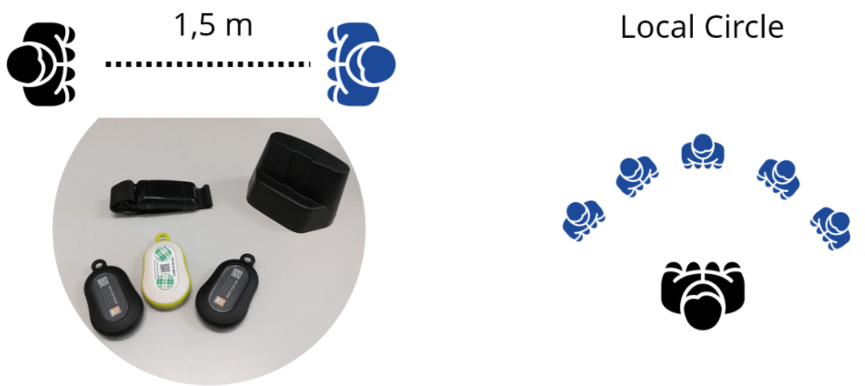

Fig. 1. The NESTORE kit for detecting proximity between users

As a result, the NESTORE user's devices keep track of all the messages propagated by devices of the local circle. The data set obtained enables to analyse such messages and to estimate the proximity between the user and a member of her/his local circle, such information is used to measure two key metrics: the amount of interactions between every NESTORE user with her/his local circle and the duration of such contacts.

The SID algorithm (Baronti et al., 2020) is used to detect the proximity between devices (emitter and receiver). SID has been designed for a Cloud-based environment. In particular, the SID algorithm runs periodically on a virtual machine of the NESTORE Cloud, performing the following two steps: (i) Extract for each NESTORE user the data collected from the receiver device; (ii) Analysing the messages and detecting the proximity between all pairs of devices (emitter and receiver). The first operation consists of extracting the messages received from a no-SQL storage unit, while the second operation consists of analysing the time series of the messages. The proximity detection exploits two features: the rate of messages lost and the RSSI of the messages received. More specifically, the lower the number of messages sent and the higher the RSSI of the messages received, the higher the probability for a pair of devices to be in proximity. Such analysis is performed for each of the NESTORE users once per day. The metrics computed are, in turn, uploaded to the NESTORE ZivaCare system providing data to the NESTORE app. Figure 2 reports an example of the user interfaces designed for the NESTORE users.

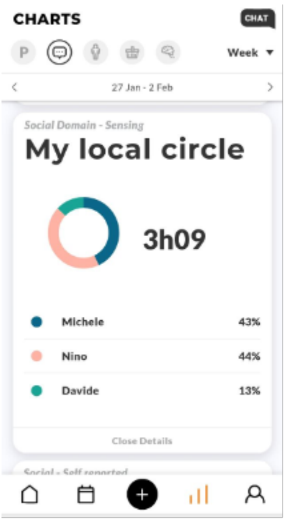

Fig 2. The local circle metrics available within the NESTORE app.

The app reports the number and the duration of the interactions with the members of the local circle. It is worth to notice that the design of the user interface has been developed considering two key aspects:

- To avoid any kind of evaluation about the amount and duration of the interactions;
- To provide simple and intuitive data, easily comprehensible for the NESTORE users.

Concerning the first aspect, it is out of the scope of this project to provide a qualitative assessment of the interactions, rather we aim to demonstrate the possibility of automatically inferring the existence of a social interaction by exploiting sensing devices based on commercial and massively available technologies (e.g., Bluetooth Low Energy protocol). Concerning the second aspect, we did not introduce not-intuitive metrics, as they might dissuade the end-users to keep using the application and hence reduce the motivation during the pilot study. Finally, we argue that the information reported to the NESTORE users (number and duration of the interactions) play the role of an incentive mechanism for the project adherence as they provide a tool to self-monitor one's own trajectory and evolution week after week.

The proximity technologies employed with the NESTORE project are now extremely diffused, as the recent COVID-19 pandemic demonstrated the effectiveness of tracing apps based on the proximity detection. However, we argue that for a better and more accurate identification of ties binding people it is required to mix multiple sources of information: speech, body orientation, and gesture. The combination of them even more helps to identify the explicit voluntariness of interaction for a dyad (pair of subjects). In fact, relying only on the proximity might introduce false positive interactions due to external factors not depending on the user's willingness to socialize. The NESTORE experience framed a path towards a better comprehension of the social domain with sensing technologies, and we are ready to follow it.

6.3 Monitoring of Cognitive Functioning in NESTORE

6.3.1 Assessing cognitive status at baseline and posttest

Cognitive functioning is multidimensional, encompassing various facets of fluid intelligence (i.e., more biologically driven abilities) and of cristallized intelligence (i.e., predominantely knowledge and experience-driven abilities). We thus assess multiple cognitive abilities at both baseline and posttest, and focus on key abilities for training, such as executive functioning and broader everyday cognition abilities in multi-domain approaches.

6.3.1.1 Trained Domains

One coaching pathways in the cognitive well-being domain focuses on a structured working memory training involving a numerical updating task that can be administered in an adaptive way such that task difficulty is continuously adapted to the current performance of an individual. To assess training gains, we assess performance in this same task at baseline and at posttest, complemented by assessements of executive functioning in two additional very standard psychometric tasks (i.e., to assess near transfer).

6.3.1.2 Transfer Domains

To assess transfer to other untrained domains (i.e., far transfer), we further measure task switching, general fluid abiliy, processing speed, attention and self-reported everyday performance.

Table 2. Cognitive Monitoring Variables and Instruments

Construct	Measurement Instrument
Cognitive Status (Baseline, Posttest)	

Task Switching	Trail Making Test B
Working Memory	N-Back
	Digit Span Backwards
	Numerical Updating
General Fluid Ability	Berlin Intelligence Structure Test (BIS-4)
Processing Speed	Digit Symbol Substitution Test
Attention	Trail Making Test A
Everyday Performance	Cognitive Failure Questionnaire
Cognitive Performance in Daily Life: Monitoring	
Working Memory	Digit Span Backwards (cognitive monitoring in daily life)
Daily everyday cognitive functioning	Everyday memory failures questionnaire

6.3.2 Assessing cognitive performance throughout the coaching phase

6.3.2.1 Computerized structured cognitive tasks

The first of two structured cognitive coaching pathways involved performance on a numerical updating task and thus train individual in the domain of working memory, a very common training domain (Guye et al., 2017). In this task users perform arithmetic operations with two to four digits that appear in a grid presented on the smartphone screen. Individuals have to either add or subtract a number to or from those digits. After performing a total of five (easy condition used in daily life; eight operations for more difficult alternative version of task that was part of the baseline and posttest assessments) arithmetic operations individuals have to enter the final digits into each cell. When accuracy equals 0.8 or higher across one session, task difficulty is increased by one level or decreased by one level if accuracy is below 0.6, which means adding an additional cell and respective digit to the grid and total number of operations.

6.3.2.2 Serious Game

The second structured cognitive coaching pathway involved a so-called serious game. For many years, researchers and developers alike have worked on producing serious games designed to train the mind (Michael & Chen, 2005). One of the

most notable examples is Brain Age, also known as Dr. Kawashima's Brain Training (Nintendo, 2005), on the Nintendo DS. Brain training games aim to prevent cognitive decline or to measure cognitive ability (Vasconcelos, Silva, Caseiro, Nunes, & Teixeira, 2012; Binder et al., 2015; Pazzi et al., 2014; Gamberini et al., 2006). While such games have proven themselves popular with audiences, empirical evidence to their usefulness in training cognitive ability is scarce (Binder et al., 2015). Often, these 'brain-games' focus on providing the player with puzzle-like tasks, such as crosswords and math problems. At the same time, evaluation of these games rarely goes beyond initial user responses, with long-term studies on their potential benefits lacking (Granic, Lobel, Engels, 2014).
Pocket Odyssey, the game developed as part of the NESTORE system and based on a serious game specifically developed for healthy older adult users and indicating successful training and transfer effects (Binder et al., 2016), consists of three components. The first is the 'Ship', which functions as the main 'hub' for the player and allows access to the other parts of the game. The other parts are the 'Gym' and the 'Submarine' mini-games (see Figure 3). The Gym game is designed for physical training and as such will not be discussed further. The Submarine game is a game for cognitive training and assessment that incorporates the tasks outlined earlier in this chapter. The first time a NESTORE user starts the game, they are welcomed by the character Nestor. He is the player's guide to the game. In the introduction, he informs the player that he requires their help in fixing up his ship. Once Nestor has established the premise of the game, he guides the player through a short tutorial that explains the basic functionality.

Fig. 3. Example map for a player to memorize (top left), the submarine game screen showing action radius and various pickups (top right), a player reaching a crossroads and choosing which direction the submarine will go next (bottom left), and the final scoring screen (bottom right).

In the Submarine game, players are asked to memorize a route on a map with a grid. Depending on the level of difficulty, the route has a certain length and therefore requires the memorization of a number of directions to turn on each juncture. At the same time, players need to steer the submarine by tilting the mobile device so that they can collect treasure in the water, all the while avoiding bombs.
After players choose the Submarine game from the main menu, they can choose to play any of the training levels. Each of these levels introduces the player to a different aspect of the game. Playing these levels is optional and does not net the player a reward. The player starts the game by pressing the main play button. This loads the last level that the player reached. First, the player is shown a route on a map. The difficulty of the route increases with level tiers. For example, between levels 1 and 5 the player needs to complete a route with 3 junctions, while levels 45 to 50 consist of routes with 12 junctions. There are multiple possible layouts for the player to receive for each level. This is to improve variability and replay-ability of the game, as well as retaining challenge.
Once the player has memorized the route, they press continue. They are then presented with a 3D environment of a submarine moving through seaweed on an ocean floor. Coins and bombs may appear along the path, the frequency and ratio of which depend on the difficulty level. Players tilt their mobile device to steer the submarine left and right. The goal is to steer the submarine close to coins and collect them by tapping the screen to earn points. The player should not tap the screen when they are in range of a bomb, as this deducts points. Whenever the player reaches a junction, they need to remember in which direction the submarine will go next and confirm their choice by tapping the corresponding button on the screen. Sound effects and a score bar inform the player of whether their choice was correct, and when they collect coins or bombs. With all the game mechanics together — memorization of a route, directing the submarine, and picking up the treasure while ignoring the bombs — the submarine game tests players' spatial navigation skills, accuracy, and inhibition.
Once players finish the route, they see their score. If they score above a certain percentage, they advance to the next level. If they performed averagely, they need to replay the level. If they performed poorly, they drop a level in difficulty. Every fifth level earns the player a star, while in-between or previously cleared levels earn the player coins. Both can be used to upgrade the ship in the main screen of the game, providing a light incentive to keep playing and reaching higher levels.

6.4 Conclusion

In NESTORE, social and cognitive monitoring occurred within a broad battery of standardized, reliable and valid instruments at baseline and posttest as well as in daily life as part of the general daily life monitoring of individuals as well as of the coaching pathways. The battery ensures a broad range of information to be fed into the Decision Support System that allows user-specific recommendations, and also an empirically sound evaluation of coaching effectiveness in both of these key domains of psychological well-being and health.

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