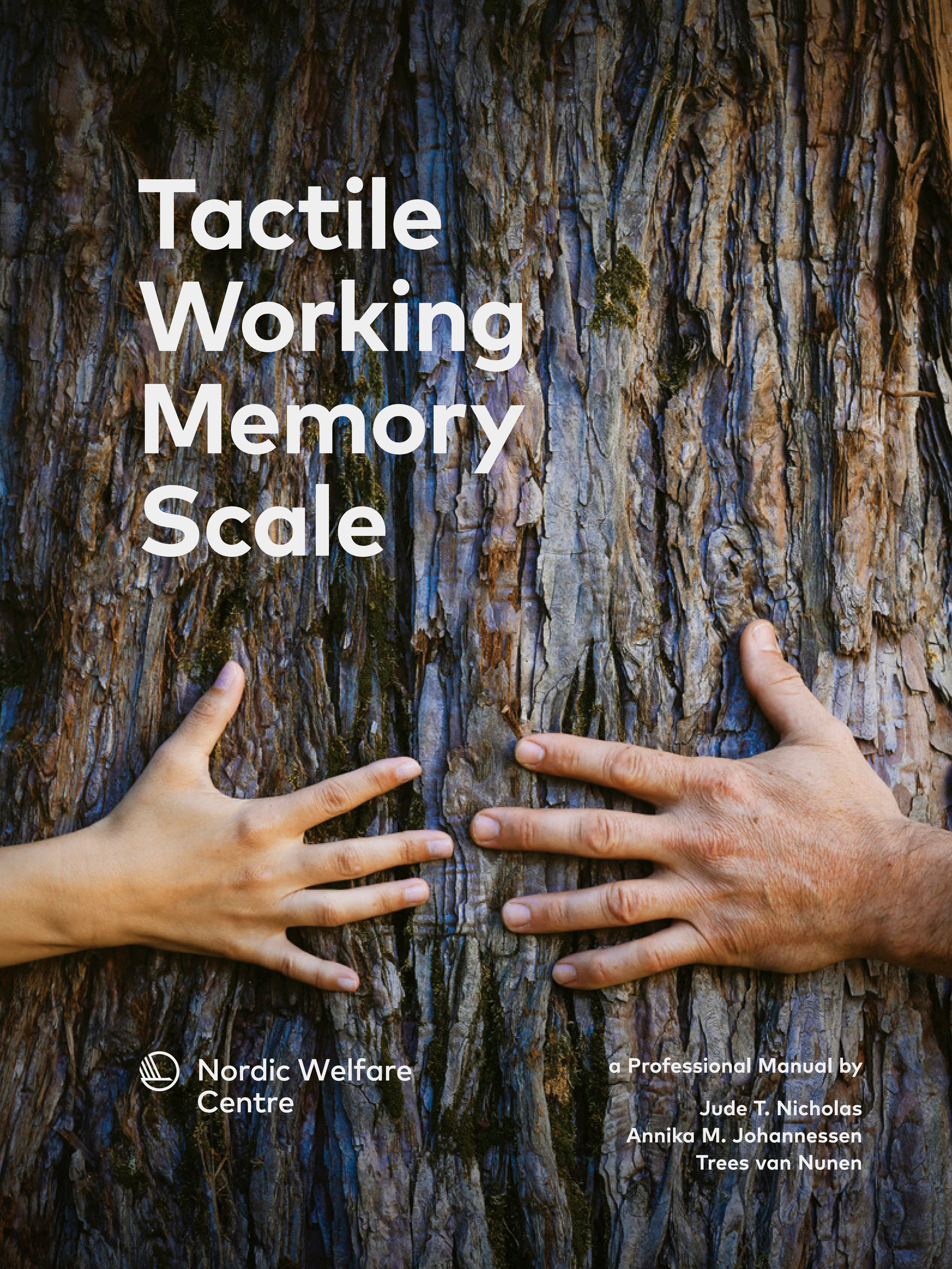

Tactile Working Memory Scale

Nordic Welfare Centre

a Professional Manual by

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NATIONAL ADVISORY UNIT ON DEAFBLINDNESS

Nordic Welfare Centre

Tactile Working Memory Scale – A Professional Manual

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FOREWORD

Somewhere in the Nordic countries, or elsewhere, a small child is born. A new little life on earth. After a short time, the surrounding people start to understand that the child develops in a way that differs from the norm. Among other things, both vision and hearing are impaired. The whole view of being changes with the term combined visual and hearing impairment, or deafblindness. Vision and hearing are central senses for us humans, and we base a large part of our communication on them. What do we do now? How should we communicate with this little person? How should we know if the child is developing cognition, the ability to handle the world?

The purpose of this manual is to make a difference for people with congenital deafblindness. By developing methods for evaluating cognitive functions in relation to congenital deafblindness, the surrounding people can get tools and strategies to ensure that these persons have the opportunities to develop and make use of all their potentials, both cognitively and linguistically.

The manual contains a theoretical overview of the basics of working memory and connects it to assessment and evaluation of tactile working memory, which is central for people with congenital deafblindness. The manual is aimed primarily at professionals whose task it is to evaluate and assess cognitive abilities of persons with congenital deafblindness, and specifically the tactile working memory.

The Nordic countries have a shared history that date back as far as the 1970:s when it comes to jointly produce, develop and disseminate knowledge in the deafblind area. This is done through research environments, politicians and at government level, as well as in the different social services whose mission it is to make assessments and carry out efforts for people with congenital deafblindness. The population of people with congenital deafblindness is small in each country. Therefore, the Nordic benefit is great. By working across the Nordic countries we have jointly developed knowledge and created greater competence environments through networks of specialists and professionals.

The Nordic Welfare Centre, an institution belonging to Nordic Council of Ministers, creates meeting places and is responsible for knowledge development networks, expert groups and education in the entire welfare area and in the deafblind area specifically. Our work is based on current research and Nordic knowledge gathering. The authors of this book are members of the expert network Cognition in relation to congenital deafblindness coordinated by the Nordic Welfare Centre, and it is on the basis of that work that these methods have been developed to evaluate the tactile working memory.

The Nordic Welfare Centre has also coordinated the work of developing a Nordic definition of the disability deafblindness to create a common Nordic basis for further work and knowledge development: Deafblindness is a combined vision and hearing impairment of such severity that it is hard for the impaired senses to compensate for each other. Thus, deafblindness is a distinct disability. The definition takes as a starting point the UN Convention on the Rights of Persons with Disabilities, which states that persons with disabilities shall have the full and equal enjoyment of all human rights and fundamental freedoms by.

All the Nordic countries have ratified the convention and the Nordic Council of

Ministers has an Action Plan for Nordic Co-operation on Disability that addresses human rights and the importance of sharing knowledge and experience.

It is our hope that this manual will enhance our shared knowledge and in particular be used as a tool for people working with people with congenital deafblindness. The ultimate goal, of course, is to make sure that people with deafblindness are ensured their human rights. Spreading knowledge is one part of working towards enhancing life quality and equal participation in society for this small group, not just in the Nordic countries but all over the world. This is one small step for equal participation in society for the new-born little child, and all persons with congenital deafblindness everywhere.

Eva Franzén
Director
Nordic Welfare Centre

It is our hope that the Tactile Working Memory Scale (TWMS) will enhance the lives of people of congenital deafblindness by increasing their participation in the evaluation of cognitive functions. By explicitly seeking their participation in the assessment process, we hope to build a bridge of communication through mutual understanding of their everyday experiences. Such a collaborative partnership in the assessment process provides a starting point for a more comprehensive evaluation of cognitive potentials, as well as a more successful intervention in the world of people with congenital deafblindness.

The aim of this manual is to give an overview of the theoretical foundations of working memory and link it to the assessment and intervention of tactile working memory. In this manual there are a series of examples to demonstrate and clarify the description of each items of the TWMS. The manual also covers several learning strategies, classified according to their particular emphases. The major emphases are on the perceptual, cognitive and social cognitive strategies.

The items of the scale could be rated through direct or video observation. The scale must be administered by professionals who have a knowledge of the person's repertoire of behaviors and good observational skills. Most valid results are obtained if several individuals having close contact with the person (teachers, support teachers, parents, specialists) evaluate the person on a consensus basis. The scale is not included in this manual but is available as a separate scoring scale.

Although the scale is developed for assessing working memory potentials in persons with congenital deafblindness, it is feasible to use the scale for people with other disabilities who have difficulties using their vision and hearing effectively and who require bodily-tactile information for communication and cognitive development, such as children with complex communication support needs or children with brain related visual and hearing loss.

"Too often we underestimate the power of a touch, a smile, a kind word, a listening ear, an honest compliment, or the smallest act of caring, all of which have the potential to turn a life around."
— Leo F. Buscaglia

Chapter 1

An introduction to Working Memory

AN INTRODUCTION TO WORKING MEMORY

1.1 What is Working Memory?

The ability to keep something in mind for a limited amount of time is a central function in cognition. Working memory has been described as a complex cognitive mechanism used to temporarily store and process information (Miyake & Shah, 1999). It is often portrayed as the mental workspace that keeps track and works with information, according to the needs of the moment. Working memory is critical for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier and relating that to what comes later (Diamond, 2013). The purpose of working memory is to build up and maintain an internal model of the immediate environment and what has been happening in our world (Bower, 1975).

Working memory can be flexibly used to support a variety of tasks performed in daily life and is widely thought to be one of the most important mental faculties, critical for cognitive abilities such as planning, problem solving, understanding complex topics and learning new things. Working memory is our ability to store and process new as well as previously obtained information, which aids in processes such as reasoning, comprehension, learning, and memory updating (Sandhu, 2002). It also has been proposed to play a critical role in communication (Rudner & Signoret, 2016).

The term working memory has been envisioned by multiple prominent working memory models, including those proposed by Baddeley and Hitch (1975) and Cowan (2008). Baddeley (2003) proposes four separate working memory components: a central executive/attention controller that focuses, switches, and divides attention and links long-term and working memory; a visuospatial sketchpad that holds visual and spatial information; a phonological loop that holds speech-based and other acoustic information; and an episodic buffer that forms an interface among working memory components and binds information from subsystems and long-term memory. On the other hand, Cowan (2008) posits that working memory may be part of a larger, more unitary construct primarily guided by the focus of attention, in addition to central executive, phonological storage and rehearsal subsystems.

Working memory is often applied in the fields of cognitive psychology, cognitive neuroscience, clinical neuropsychology, linguistics as well as applications to issues in language education, neuro-rehabilitation and special needs education.

Research on working memory has focused on the fundamental building blocks that allow us to handle representations of our immediate environment. Working memory plays a causal role in children's developing skills (Gathercole & Pickering, 2000), educational achievements (Alloway et. al., 2008; Chalmers & Freeman, 2018), auditory skills (Brenneman, et al., 2017), speech recognition in noise (McCreery, et.al., 2017) and in arithmetic performance (Wu, et al., 2008). For instance, when solving a math problem, we must access and hold representations of the numbers to be manipulated in working memory in order to derive an answer.

1.2 Working memory and language

There is increasing evidence suggesting that working memory and language are strongly linked. Working memory plays a key role in supporting children's language learning over the school years, and beyond this into adulthood (Alloway, 2006; Engel de Abreu, Gathercole, & Martin, 2011). Scientific studies have shown strong links between working memory and vocabulary acquisition (Gathercole & Alloway, 2008), learning a new language (Bosman & Janssen, 2017), linguistic processing (Archibald, 2017) and speech perception (Heine & Slone, 2019).

Working memory is critical for language comprehension because it serves as a temporary holding area for incoming and outgoing information, as well as a storage space for linguistic information during immediate processing (Baddeley, 2007). Successful language comprehension requires not only an understanding of words and utterances in isolation but also the ability to integrate utterances to build a rich, coherent mental representation of the objects and events specified in such utterances and the relations between them (Bishop, 1997). Working memory has an important role for on-line language processing during verbal communication; it is used to maintain relevant semantic information, to inhibit the processing of irrelevant auditory stimuli, and to selectively attend to a specific audio stream during conversations (Borghini & Hazan, 2018).

Working memory also plays a significant role in sign language (Wilson & Fox, 2007). Sign language working memory appears to have an impact on deaf signers' signed language proficiency (Boutla, et. al., 2004). Interestingly, Wilson and Emmorey (2003) have proposed a sign-based phonological loop in deaf signers, which comprises of two components: a phonological store that retains information using sign-based phonological codes (e.g., handshape, orientation, location, and movement), and a manual articulatory rehearsal mechanism that refreshes information in the phonological store. However, these studies have suggested that working memory does not rely on a dedicated language architecture, but instead involves the strategic recruitment of resources as needed for the task demands.

1.3 Working memory and executive control

Executive control processes are involved in the regulation of working memory. In other words, executive control processes are called upon when you must concentrate and maintain attention in conditions requiring a lot of attentional resources.

A close link between the executive control processes of working memory and executive functions has been suggested (Miyake, et al., 2000; McCabe, et. al., 2010). The concept of executive functions is defined as a set of mental control skills that are necessary for monitoring behaviors that facilitate the attainment of chosen goals, where working memory is a core component (Nicholas, 2005).

There are three core dimensions of executive function skills: (1) working memory; (2) inhibitory control (the ability to master thoughts and impulses to resist temptations, distractions, and habits, and to pause and think before acting); (3) cognitive flexibility (the capacity to switch mental gears and adjust to changing demands or priorities). However, these three core dimensions of executive functions covariate and should not be viewed as three separate cognitive processes (Kane and Engle 2003; Diamond, 2013). In other words, inhibitory control supports working memory processing as it removes unnecessary information which in turn facilitates goal maintenance, working memory supports inhibitory control by providing information on what is the goal which in turn facilitates decision on what is irrelevant to process, and cognitive flexibility requires involvement of both inhibitory control and working memory (Diamond 2013).

"Inhibitory control supports working memory processing as it removes unnecessary information."

1.4 Working memory and subsystems

There is considerable debate on whether working memory is characterized by distinct subsystems for specific sensory stimuli (modality-specific) or by underlying processes that are shared between different sensory stimuli (modality non-specific). Although working memory capacity is best thought of as predominantly a modality non-specific, there is evidence supporting a functional dissociation between auditory and visual working memory (Cocchini, et. al., 2002; Fougnie & Marois, 2011; Egeland, 2015; Adams, Nguyen, & Cowan, 2018). Differences between auditory/verbal versus visual/spatial working memory have been found in both children (Jarvis & Gathercole, 2003) and adults (Jurden, 1995). This is further supported by a recent study that suggests for the existence of modality-specific working memory systems and highlights the significance of assessing both auditory and visual working memory in a clinical group (Park & Jon, 2018). Besides, modality-specific differences in working memory play an essential role in language outcomes (Gathercole & Pickering, 2000). For instance, a longitudinal study on working memory in children with specific language impairment had found that modality-specific working memory deficits were linked to language problems (Vugs, et. al., 2017).

Why is there a functional dissociation between auditory and visual working memory? The functional dissociation between auditory and visual memory factors may arise from additional modality-specific components to the tasks, possibly reflecting the contributions of modality-specific storage systems (Baddeley & Logie, 1999). This might suggest that rather than there being a general limit on working memory, there is a limit to the amount of information which can be retained in storage modules for the auditory and visual modalities (Cohen, et.al., 2011).

While mechanisms underlying working memory processes in the visual and auditory modality have been studied intensively, the principles underlying working memory in the tactile modality are much scarcer. However, in the last decade there has been an increase in the number of research studies directed at understanding working memory in the tactile modality. Several studies have examined tactile working memory in normal subjects (Bliss & Hämäläinen, 2005; Bonino, et al., 2008; Savini, et.al., 2012). Furthermore, a research study demonstrated enhanced tactile working memory functions in the blind compared to sighted subjects, indicating that modality-specific experiences play a crucial role in shaping tactile working memory (Cohen, et. al., 2011).

The terms tactile and bodily-tactile will be used interchangeably in this manual with the same meaning.

1.5 Why is it important to understand tactile working memory in persons with deafblindness?

Deafblindness is a combination of hearing and vision loss. Deafblindness is a combined vision and hearing impairment of such severity that it is hard for the impaired senses to compensate for each other. Deafblindness therefore presents a distinct disability in relation to the surrounding environment (Nordic Welfare Centre, 2016). The two sensory impairments multiply and intensify the impact of each other, creating a severe disability, which is unique (Knoors & Vervloed, 2003). Since one sense cannot compensate for the other, the functional consequences of deafblindness are distinct from those experienced by persons who have a visual impairment or hearing impairment. The functional effect of deafblindness deeply affects the individual`s mobility, communication, learning, linguistic skills and understanding of the world.

Deafblindness may be acquired or congenital. In persons with acquired deafblindness (ADB) the sensory impairments develop later in life. Conversely, congenital deafblindness (CDB) describes a person who is born with combined vision and hearing loss before they have developed means of communication or language.

The term congenital deafblindness covers a spectrum of combinations of varying degrees of vision and hearing loss. Children and young adults who are deafblind differ by type and level of hearing and vision loss, age of onset of vision and hearing loss, physical and health issues, cognitive functioning, expressive and receptive communication forms, and educational histories (Bruce, et. al., 2018). The combined peripheral hearing and visual impairments associated with congenital deafblindness severely diminish access to information from the environment. Furthermore, concomitant brain injury, physical impairments, motor/movement disorder (eg. cerebral palsy) or brain related visual and hearing loss could impede opportunities for mobility, communication, learning and language development.

The term brain related visual and hearing loss could be used when a neurological impairment is affecting the normal functioning of vision and hearing. The eyes or ears may function normally, but the visual and auditory systems of the brain do not consistently understand or interpret what the eyes see and the ears hear. It refers to a condition of impaired processing of both visual and auditory information due to central hearing and visual impairments. Besides, the functional consequences of brain related visual and hearing loss may be similar to the combined effects of Cerebral Visual Impairment (CVI) and Auditory Processing Disorder (APD). Individuals with CVI may have visual processing problems that interferes with their ability to, for example, recognize familiar objects, understand facial expressions or recognize familiar persons, whereas individuals with APD may have auditory processing problems that interferes with their ability to, for example, distinguish similar sounds from one another or listen in noisy environments. Given the difficulties in identification and assessment, it is not difficult to see why most children will not appear on the radar for a brain related visual and hearing loss (Aitken, 2010).

Visual and auditory cues play an important role in communication long before language itself is acquired. The availability of visual and auditory stimuli is therefore assumed, to a great degree, in early adult–child interactions. Much communication is guided via the visual and auditory processes. Making eye contact, watching expressions on the faces of others and listening to the voices are important steps in early communication development. Thus, one cannot understand the impact of deafblindness by adding up the effects of the vision loss and the effects of the hearing loss (Bruce, et. al., 2018).

Children with CDB face greater demands compared to sighted and hearing children in understanding how to relate to the world. The combined hearing and visual loss lead to a deficit of available cues from their surroundings that result in fragmented experiences. Accordingly, the child with significant visual and auditory loss faces immediate and lasting disadvantages that affect many aspects of the potentials needed for communication development. People with CDB experience complex problems in communicating because of their severe visual and auditory disabilities (Bruce, 2005), and their attempts to communicate may not be recognized by others. From the very beginning, there is a mismatch between the immediate behavior repertory of the child with congenital deafblindness and the reactive behaviors of the adult (Nafstad & Rødbroe, 1999).

The commonality between people with deafblindness in various degrees is also that they perceive information mainly or only through the tactile senses (Damen, 2019). The tactile sense or the sense of touch includes multiple types of sensation received from the surface or inside the body (see chapter 2.1.1).

People with deafblindness are skilled at many things, but we can fail to notice this when we focus on the problems and challenges, instead of recognizing the qualities and potentials of each individual. We should not view deafblindness, however, as a negative state of being in which sight and hearing are not there but instead as a positive state in which active touch, bodily movements, postures and hand gestures, are the pre-eminent source of information.

The bodily-tactile sense could be considered as the primary modality of communication and learning for many of the individuals with deafblindness. Little incidental learning will occur due to the loss of distance senses, and touch will be an important sense for learning (Silberman, Bruce, & Nelson, 2004). Hence, supporting early social interaction, communication and language development by using the bodily-tactile modality is today the dominating intervention approach in congenital deafblind education in many countries.

Children with CDB need to be supported in progressing as far as possible in acquiring language in a bodily-tactile modality. The congenital deafblind child must acquire language within the bodily-tactile modality, because that is the primarily communicative access to the world (Dammeyer, et. al., 2015). It is assumed that the heightened sensitivity to tactile stimulation is the main source of perceptual information and in the emergence of tactile sign constructions in persons with CDB, even in those persons who retain residual hearing and/or vision (Forsgren, Daelman & Hart, 2018).

People with CDB show that they can become very skilled in using the tactile modality as a source of information (Janssen, et. al., 2007) and can learn a tactile language (Lindström, 2019). It is through the tactile sense that a child with congenital deafblindness can most easily unlock his or her curriculum (Vonen, 2019).

When hearing and vision are lost simultaneously there is a high risk that the processing of information will be fragmented or limited, especially if the func-

Multisensory integration and cross-modal neuroplasticity

Multisensory integration refers to the merging of information from different senses (vision, hearing or bodily-tactile). For example, the purpose to use vision to guide exploratory hand use, is not necessarily to substitute for the bodily-tactile sense, but rather to guide hand manipulation, and make the sensory input meaningful.

Cross-modal neuroplasticity is the adaptive reorganization of neurons, when the disruption of sensory input from one sense improves the function of the remaining senses. For instance, after visual deprivation, neuroplastic changes occur such that that the visual cortex is recruited to process sensory information from other senses, such as hearing.

Cross-modal neuroplasticity is the reason why individuals with blindness often have enhanced auditory abilities, primarily because of the recruitment of visual brain areas to carry out auditory localization (Gougoux, et. al., 2005) or why people born deaf are better at processing peripheral vision and motion, primarily because of the recruitment of the primary auditory cortex to process vision and motion (Bavelier et. al., 2001; Scott, et. al., 2014).

tional use of residual vision and hearing is not supported by the bodily-tactile sense. Individuals who are deafblind benefit from interventions compensating for their limitations in audition and vision, as well as from an environment that allows them to make the best use of their bodily-tactile senses. Hence, by supporting the bodily-tactile ability of people with deafblindness in their everyday lives, we may be able to help them create unique experiences, promote multisensory integrative capabilities and strengthen cross-modal neuroplasticity in the nervous system (see page 17 Multisensory integration and cross-modal neuroplasticity).

There is evidence showing that the representation of tactile information interacts with information about other sensory attributes of objects or events that people perceive, suggesting that multisensory information-processing networks play a leading role in the storage of tactile information in the brain (Gallace & Spence, 2009). This emulation, created by networked brain activity, is integrated and mapped for vision, hearing and bodily-tactile sensations. Although our sensory experiences are most likely multimodal in nature, we nevertheless need to have a pragmatic understanding of the sensory, perceptual and cognitive functioning through a unimodal approach, especially to have a clear idea of how bodily-tactile information is processed in people with deafblindness.

Based on the assumption that the person with congenital deafblindness may be finer equipped at perceiving the world from a bodily-tactile perspective, we must be willing to move towards a better understanding of the working memory processes in the bodily-tactile modality. This modality-specific approach of working memory might help us understand the person's cognitive architecture in two ways:

a) how to identify the behavioral manifestations of tactile working memory functions in individuals deprived of both vision and hearing.
b) how to design specific interventions targeted to improve working memory functions in individuals deprived of both vision and hearing. Subsequently, we need to understand the features of tactile working memory through the cognitive information processing theory.

1

Chapter 2

A framework to guide the assessment of tactile working memory

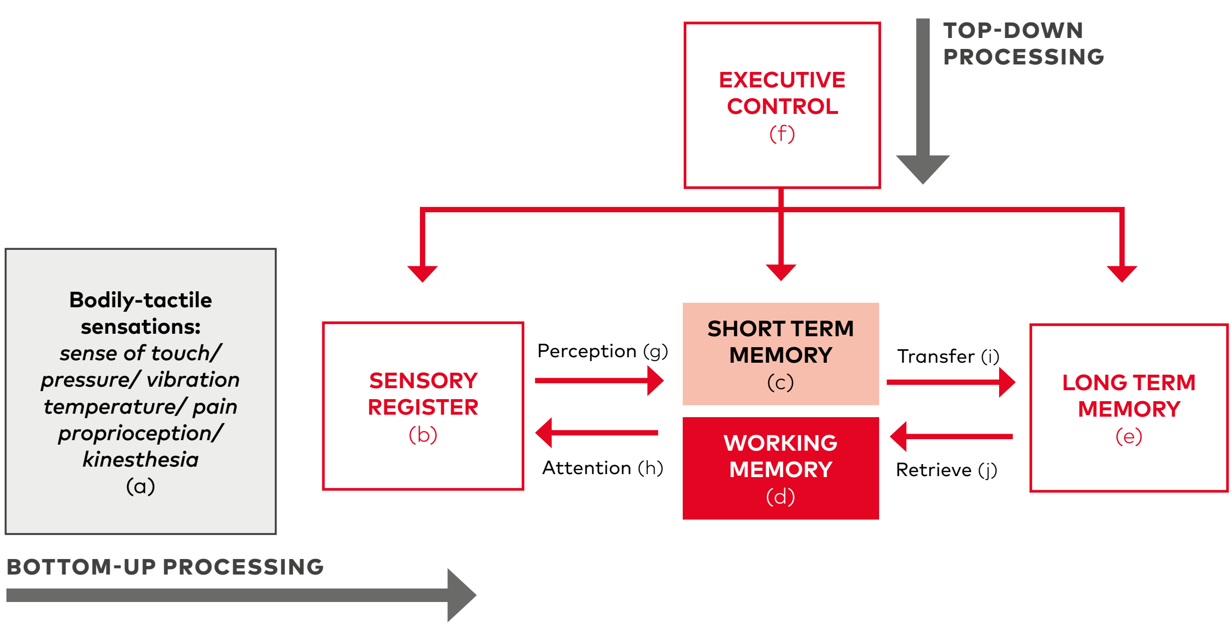
2.1 Understanding tactile working memory within the cognitive information processing theory

The cognitive information processing theory is a generic name applied to various theoretical perspectives dealing with the sequence and execution of cognitive events. The cognitive information processing theory of tactile cognition deals with the study of the information flow and the analysis of the sequence of events that occur in a person's mind while receiving a new piece of bodily-tactile information. The information processing starts very early by seeking out, focusing, and selecting particular aspects of the available information. This theory has been integrated with findings from cognitive neuroscience to include the idea that information processing has been found to be created by a collection of neural systems, working interdependently (see chapter 2.1.3).

The cognitive information processing theory also describes capacity limitation within the processing system. This means that the amount of information that can be processed by the system is constrained in some very important ways. Bottlenecks, or restrictions in the flow of information, occur at very specific points and is often referred as resource-limited processes (Norman & Bobrow, 1975). For example, working memory has a limited capacity and errors often occur at higher working memory loads (Bouchacourt & Buschman, 2019). Nevertheless, the cognitive information processing theory emphasizes cognitive strategies to overcome these limitations (see chapter 4.3).

According to cognitive information processing theory, somatosensory processing in contrast to visual or auditory processing, is about how bodily-tactile infor-

Figure 1. The somatosensory processing system: how received bodily-tactile sensations can be processed in the loop of several processing units through which they pass. The processing units (a, b, c, d, e, f) and the chain of information processing (g, h, i, j) are illustrated in the figure. The two arrows (black and grey) that symbolize bottom-up processing and top-down processing are also illustrated.



mation is systematically processed, organized and integrated, so that the person may use the information to interact effectively with the surrounding world.

The cognitive information processing theory states that the bodily-tactile sensations that have been received can be processed in the loop of several processing units through which it passes. These processing units are the sensory register, short term memory, working memory and long-term memory. Additionally, this processing system involves an executive control function that oversees the fundamental processing units. The different processing units that are required for receiving, processing and interpreting bodily-tactile information to build a representation of the physical environment, is referred to as the somatosensory processing system (See Figure 1).

2

2.1.1 Functional characteristics of the somatosensory processing system

The somatosensory processing system is responsible for systematically selecting, processing, organizing and integrating bodily-tactile information.

Somatosensory processing involves multiple types of sensations from the body. These bodily-tactile sensations (figure 1a) are formed from several physical sensations and controlled by a huge network of nerve endings, neural fibers and somatosensory receptors in the skin.

The bodily-tactile sensations of the somatosensory processing system are organized into three groups. The first group is that of discriminative touch and involves light touch, pressure and vibration. The second group involves temperature and pain, and the third group involves proprioception.

Proprioception is the sense of knowing your body's relative position in space. Proprioception allows us to appreciate posture changes even in the absence of visual information. In other words, it is the sense that lets us perceive the orientation, location and movement (kinesthesia) of parts of the body at any moment in time. Proprioception along with vision and the vestibular system is part of the balance sense. Proprioception is coordinated by proprioceptors that are found primarily in muscles, tendons and skin (see table 1, page 35).

Like proprioception, discriminative touch, temperature and pain are mediated by specialized sensory receptors in the skin (see table 1, page 35). Consequently, our ability to sense touch and all the bodily sensations we feel appear to encompass several distinct sensory systems and should perhaps be considered more of a multisensory rather than a single sensory modality (Gallace & Spence, 2009). Furthermore, recent evidence has provided insight on the neural mechanisms that may influence pleasant touch. (Perini, Olausson & Morrison, 2015). Pleasant touch is an emotional form of touch that transmits socially relevant information (affective touch) and relies on bodily contact. In fact, what we commonly call the sense of touch, actually comprises the processing of light touch, pressure, vibration, temperature, proprioception, pleasure and pain. See Figure 2, page 24.

The multiple types of sensations from the body (bodily-tactile sensations) are initially received by the *sensory register* (figure 1b, page 22), for a period of brief

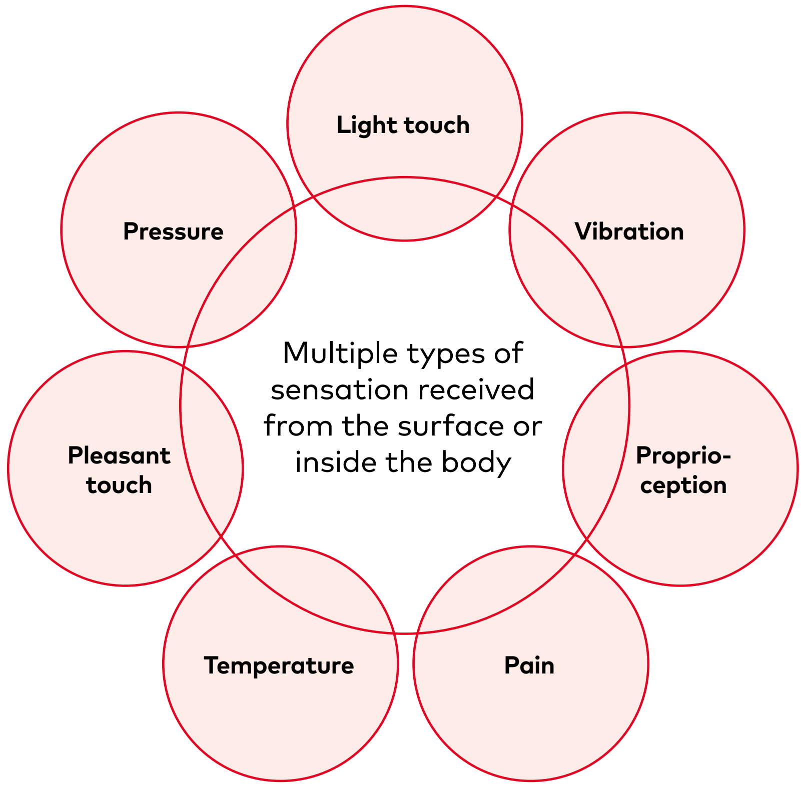


Figure 2. The sense of touch comprises the processing of multiple types of sensation from the body.

storage, which is the first stage in the loop of processing units in the somatosensory processing system. The sensory register for bodily-tactile sensations is referred as tactile sensory memory. The tactile sensory memory is believed to involve a sensory register that retains physical sensations of touch and enables people to remember tactile sensations (Gallace, Tan, Haggard, & Spence, 2008).

The initial interpretation of bodily-tactile sensations that serve as a basis for further processing is called *perception* (figure 1g page 22). Perception that involves the detection, selection and categorization of bodily-tactile sensations is referred as tactile perception. For instance, how we know what water feels like is based on our ability to generate the perception of skin wetness based on the sensations of light touch, pressure, vibration and temperature. Since there are no wet receptors in the somatosensory system, we learn to perceive wetness through the combination of bodily sensations as a result of the interaction between the sense of touch and moisture (Filingeri, et. al., 2014; Filingeri & Ackerley, 2017).

Tactile perception is the ability to select bodily-tactile sensations from the surrounding environment and to interpret it within the framework of existing knowledge using active touch and motion. Active touch refers to the act of touch and implies voluntary, self-generated movements, such as reaching/grasping, pushing/pulling, stationary/moving etc. Likewise, motion refers to a particular action, body movement or gesture. Through active touch and motion, the external environment is directly explored using the hand/body in order to gather information about the surface properties (texture, hardness/softness, temperature) or the physical dimensions of objects (size, shape, weight,).

Closely related to tactile perception is the term haptic perception. Haptic perception in its broadest sense relates to the use of active touch and motion and refers to the sensory experience associated with use of the hands/body within active exploration (Prytherch, & McLundie, 2002). The term tactile perception and haptic perception will have the same meaning in this manual.

It has been suggested that the tactile perception of object properties is tightly bound to a set of distinct purposive exploration patterns or movements called exploratory procedures. Lederman and Klatzky (1987) found that people use several exploratory procedures to explore and identify objects. For example, when a person is attempting to determine whether a surface texture is smooth or rough, he/she will be likely to explore using a specific exploratory procedure, such as a rubbing/stroking action. These distinct active manual exploratory procedures are necessary for individuals to collect information about the objects in their environment (see figure 3).

Exploratory procedures follow a developmental progression, hence, early grasping and fingering in infants may be precursors of the exploratory procedures. Pre-schoolers spontaneously show dedicated exploratory patterns not only when a target dimension such as hardness is explicitly mentioned, but when its appropriateness arises in tool use. For example, they use pressure to test a stirring stick to ensure that it is sufficiently rigid for the substance that must be stirred (Klatzky, et. al., 2005). Appropriate exploration is also found when blind children match objects on designated dimensions (Withagen et. al., 2013).

Exploratory procedures are essential in the development of object manipulation skills. Object manipulation skills are required when individuals dexterously use a wide variety of tools, for example, when using simple hand-held tools such as a hammer or chopsticks or when using more complex input–output relationship tools such as a computer mouse. As mentioned above, tactile perception is the ability to select bodily-tactile sensations, but it is also about how to explore and gather tactual information from the surrounding environment. Hence, it is described as an active learning process.

This tactile perceptual learning process involves the acquisition of information about the tactile qualities of objects, such as their texture, weight, or temperature that cannot be gathered from a distance. It requires immediate proximity

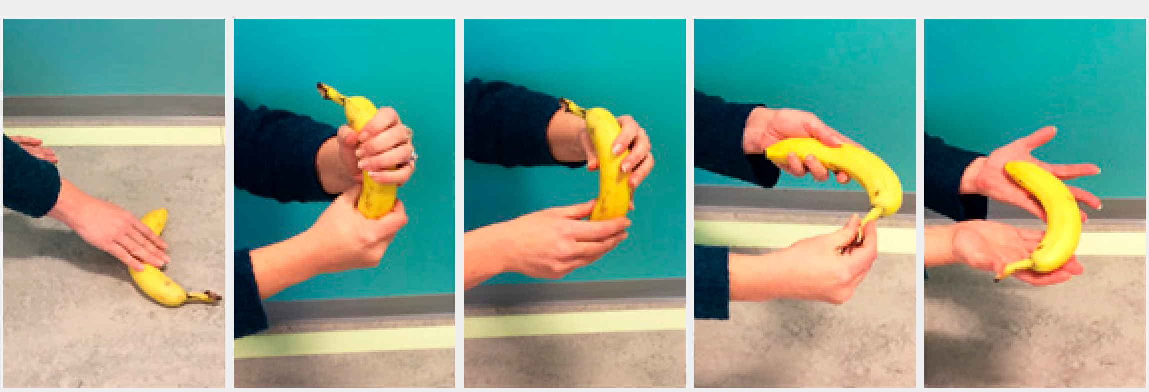


Figure 3. Exploratory procedures to identify a banana. The example demonstrates: **(1) Lateral motion** (rubbing/stroking action) for encoding the texture of the banana, **(2) Pressure** (pressing into the surface, bending or twisting) for encoding the hardness of the banana; **(3) Enclosure** (framing closely to the object's surface) for encoding the global shape of the banana, **(4) Contour following** (following the object's surface or edges) for encoding the exact/detailed shape of the banana and **(5) Unsupported holding** (lifting, hefting or wielding) for encoding the weight of the banana.

to the object (objects in the immediate vicinity). Tactile perceptual learning also requires that information be gathered over time by systematically exploring an object one aspect at a time. This may require self-generated movements and/or exploratory procedures to tap into different tactile perceptual processes such as the detection of the physical dimensions/surface textures of an object (awareness), the matching of an object (similarities), the discrimination of an object (differences) and the identification of an object or a place (labelling).

Examples of tactile perceptual learning would include the following;

1. to systematically explore the surface textures (soft/hard, smooth/rough), the thermal aspects (hot/cold) and the physical dimensions (size, shape, weight) of an object (tactile systematic exploration);
2. to compare objects that are similar and contrast objects that express differences (tactile object identification);
3. to identify the placement of an object in the immediate surrounding (tactile object location);
4. to identify a location when moving about through an environment (tactile spatial reasoning/ spatial navigation).

When tactilely identifying a location when moving through an environment, the information on the characteristics that would allow for a more precise level of navigation are important. Such as, determining one's location in the environment, knowing which direction one is facing, knowing the direction of one´s body movements, tactilely estimating the distance between objects and how near or far away they are and identifying key obstacles in the environment. This includes identifying a tactually accessible pathway that can be traced with hands or cane (Edwards, 2015). The use of perceptual training has been shown to enhance cognitive functions, such as working memory (Parsons, et. al. 2014). **Strategies** that enhance tactile perceptual learning are referred as **perceptual strategies** (see page 67).

"Attention facilitates target processing and enhances working memory."

Tactile perceptions must be encoded to form representations of reality, and these representations will be affected by the processing units of the somatosensory system. Although tactile perception enables us to retain an amount of bodily-tactile information accurately, the information will disappear unless it receives attention from short term memory or working memory. **Tactile short-term memory** (see figure 1c, page 22), is typically conceptualized as a unitary storage buffer that stores bodily-tactile information passively, temporarily and is generally seen as a limited capacity memory store.

Conversely, **tactile working memory** (see figure 1d, page 22), refers to the mental processes involved in retaining relevant bodily-tactile information in an active and readily available state over time. In other words, tactile working memory is essential for keeping in mind relative priorities of bodily-tactile information at any given time.

There is a close link between working memory and **attention** (see figure 1h, page 22) in information processing. Attention facilitates target processing and enhances working memory. For instance, directed attention can modulate the maintenance of different kinds of information in working memory (Lepsien, Thornton, & Nobre, 2011). Thus, working memory directed attention is necessary for: (1) orienting towards or attending discretely to objects in the surroundings (tactile focused attention) (2) staying focused on a task/activity for continuous periods of time (tactile sustained attention). Tactile sustained attention is the vigilant focus on bodily-tactile information and is considered a basic attentional function.

According to the cognitive information processing theory, working memory is reciprocally linked to **long term memory** (figure 1e, page 22). Working memory is crucially dependent upon stored long-term information. There is a continuous transfer of information between long-term memory and working memory. As follows, tactile working memory serves as the primary "binding unit" between tactile sensory-perceptual information and tactile long-term memory. The bodily-tactile information that we attend to and integrate into our knowledge structures is transferred (figure 1i, page 22), into long-term memory. For instance, when the tactile sensory-perceptual information has been repeated or rehearsed enough times, it is transferred to long-term memory. This type of rehearsal strategy is referred as a maintenance rehearsal strategy and it is an example from the group of **cognitive strategies** called **"maintenance cognitive strategies"** (see chapter 4.2.2).

Information is also **retrieved** (figure 1j, page 22) by reactivating information, from long-term memory into working memory in order to make sense out of new information. The term long-term memory refers to the unlimited capacity memory store that can hold information over lengthy periods of time. Accordingly, tactile long-term memory refers to the persistence of learning in a state that can be revealed at a later occasion, just by using active touch and motion. Examples of tactile memory include the following;

1. to recognize a familiar object by associating an object with a memory of the object (tactile object recognition);
2. to recognize a familiar location by associating a location with a memory of the place (tactile spatial recognition).

The information in the long-term memory can be efficiently accessed with memory cues and recalled in working memory for further cycles of processing and elaboration. This type of memory strategy is referred to as a retrieval cue strategy and is an example from the group of **cognitive strategies** called **"long-term working memory strategies"** (see chapter 4.2.1).

Modern cognitive theories often distinguish between two forms of declarative memories that can be consciously recalled from long-term memory: semantic and episodic. Semantic memory refers to general factual knowledge and can be considered to be a more structured record of facts, concepts and meanings about the external world (conceptual knowledge) that we have acquired. For instance, during tactile object recognition, the mental representation of a real object (key) is used to access the semantic properties (its use and function) in semantic long-term memory.

Tactile memory systems are involved in the storage and retrieval of information about objects that people explore using active touch and motion (Gallace & Spence, 2009).

"Specific events over time become merged into a generic script."

Memory processes not only play a role in remembering whether a specific item was encountered (recalling or recognizing a given tactile object) but also to remember a context of tactile experiences which most likely influences episodic memory. Episodic memory refers to memory of experiences and specific events. A further category of episodic memory is referred to as autobiographical memory. Autobiographical memory moves beyond recall of experienced events to integrate perspective, interpretation and evaluation across self, other, and time in order to create a personal history (Fivush, 2011).

Autobiographical memory is a personal history for specific events or experiences in one's life. Specific events over time become merged into a generic script. This script encapsulates the key experiences and actions considered typical of the event, such as "going-to-the-dentist" or "going-to-the-beach" scripts. After the specific event has become consolidated into the script, only distinctive events are likely to be specifically remembered. Life events associated with strong emotional reactions are better remembered compared to other events (Kensinger, Garoff-Eaton, & Schacter, 2007).

Autobiographical memory and their meanings link past experiences to present and future actions. Besides, they are carried out in the complex world of social relationships. A research study has suggested that engagement with a person with CDB in meaningful and stimulating shared outdoor activities and by focusing on the deafblind person's bodily-tactile gestures in a narrative structure supported the development of the deafblind person's bodily-tactile autobiographical memory (Gibson & Nicholas, 2017). This type of memory strategy that helps us remember personal episodic events is referred to as a narrative memory strategy and it is another example from the group of **cognitive strategies** called **"long-term working memory strategies"** (see chapter 4.2.1).

Finally, **the executive control** (figure 1f, page 22) processes of working memory are required to oversee the selecting, organizing, shifting, inhibiting and monitoring of somatosensory information when achieving purposeful goals (Katus, Müller, & Eimer, 2015). A distinction is drawn between tasks that involve automatic control and those that require voluntary control. Automatic control is unintentional, unconscious, and is involved in spontaneous tasks. Voluntary control, on the other hand, is conscious and is involved in effortful tasks that demand high levels of concentration, such as in unfamiliar or novel tasks/activities. We tend to make many errors and solve the novel problems rather slowly when we are involved in an unfamiliar or novel task/activity. In this way the executive control of working memory seems to be necessary to adequately engage voluntary control during tasks that involve a higher mental workload.

The executive control of working memory is responsible for three different attentional skills that play a critical role in conditions that require a lot of attentional resources:

1. when moving the focus of attention back and forth between different tasks/activities (attentional shifting);
2. when keeping track and evaluating one's own behavior in order to determine when a different approach would be more appropriate (self-monitoring);
3. when selectively processing the attended information while simultaneously inhibiting the irrelevant or competing information (selective attention).

In other words, selective attention is the ability to pay attention to specific information but not to other distracting information. During selective attention, working memory is involved in selecting task-relevant information and minimizing interference from irrelevant information (Hasher, Lustig, & Zacks, 2008). It has been shown that individuals with high working memory capacity are better at ignoring the distracting information and maintaining attention to the relevant information, while simultaneously keeping track of one's own behavior during problem solving (Sorqvist 2010). Consider how a competent player of blitz chess reacts unreflectively to the solicitations on the chess board. To count as a competent player of chess, the player must be able to distribute attention over a number of chess play factors, be on guard, ignore distractions, overlook the moves and be able to adjust when particular performances are unsuccessful.

Cognitive strategies that enhance our ability to switch mental gears (attentional shifting), to notice and fix our mistakes during an activity/problem solving task (task monitoring) and to filter distractions in a flexible way (selective attention) are called **metacognitive strategies** (see chapter 4.2.3).

In sum, working memory is a dynamic process that works in concert with other equally complex processes, such as perception, attention, memory and executive control. See figure 4, page 30. Practice and using different strategies (perceptual, cognitive, metacognitive) are ways of enhancing working memory and lowering the limited attentional resource of performing an unfamiliar, novel or complex task.

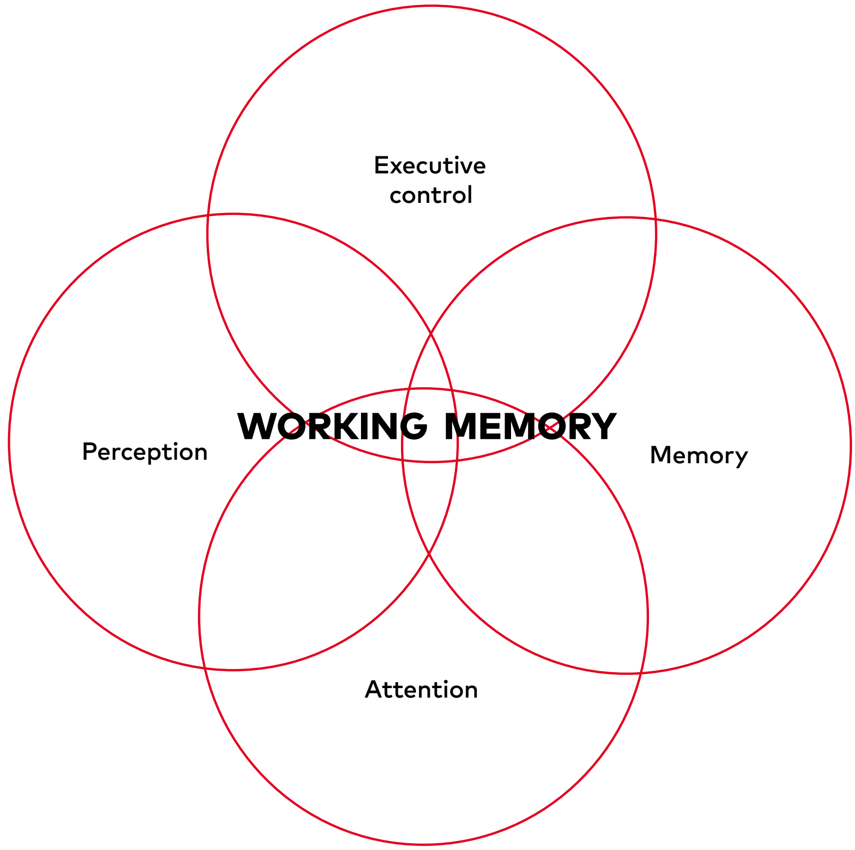


Figure 4. There is a remarkable overlap between working memory and other processes of cognition.

2.1.2 Working memory in social contexts: social working memory

Everyday social interaction involves a great deal of information processing. Whether smoothly navigating a busy social gathering with many people or keeping track of another persons' point of view during a conversation, we will need to keep track of who said what, as well as why he or she said it. As the complexity within the social situation increases the social information load increases as well. Thus, we will need to hold the social information in mind in an efficient way. Smooth social interaction requires keeping track of various amounts of social information, such as to process, store, and apply information about other people and situations. This social dynamic process that engages working memory by distilling social experiences into meaningful and flexible representations for the purpose to navigate in the social world is referred as social working memory.

Social working memory is the ability to maintain and manipulate social cognitive information in mind (Meyer & Lieberman, 2012; Meyer, Spunt, Berkman, Taylor, & Lieberman, 2012; Thornton & Conway, 2013). To understand our social world, we must continuously update information about the other person's current intentions and motivation and adapt our own behavior accordingly. Social working memory is needed to keep in mind what has occurred in the past and then integrate this social information in order to achieve a cohesive understanding of the present. The purpose of social working memory is to build up and maintain an internal model of the immediate social environment and what has been happening in our social world (Meyer, et.al., 2012).

Social working memory is distinctively linked to effortful social cognition (Meyer, Taylor, & Lieberman, 2015). Social working memory interacts with social cognition in a diversity of meaningful ways and is central to successful functioning in a social context.

Social cognition is a complex dimension of human mental development that is vital to social communication, social-relatedness, collaboration and competition, culture, and mental health (Mundy, 2018). Social cognition is defined as 'the mental operations that underlie social interactions, including perceiving, interpreting, managing, and generating responses to socially relevant stimuli, such as the intentions and behaviors of others' (Green, et al. 2012). Thus, social cognition underpins our ability to understand the behavior of others and to respond appropriately in social settings.

Social cognition has different components and is about:

a) how do we perceive and recognize the emotional states of others based on facial, gestural, bodily posture and prosodic cues (emotion perception)
b) how do we evaluate our behavior in the moment to make sure that the behavior is consistent with how we want to behave and how other people expect us to behave (social monitoring)
c) how do we reason and figure out the intention or purpose behind other people's behavior in terms of underlying mental states (e.g., needs, desires, beliefs, feelings, goals and reasons) (mentalizing)
d) how do we understand that other people's thoughts and beliefs may be different from our own and to consider the factors that have led to those mental states (theory of mind); and
e) how do we recognize another person's point of view (perspective taking).

Perspective-taking is sometimes characterized along two dimensions: **cognitive** and **affective**. Cognitive perspective-taking may be defined as the ability to infer the thoughts or beliefs of another agent, while affective perspective-taking may be defined as the ability to infer the emotions or feelings of another agent (Healey & Grossman 2018). There is evidence suggesting that targeted social working memory training could improve social cognitive processes, such as perspective-taking (Meyer, Taylor, & Lieberman, 2015) and theory of mind (Guo, et. al., 2018).

Social working memory like social cognition develops over the course of childhood and adolescence. To develop social working memory skills, children need many opportunities to experience and practice with adults and peers. As children grow, they become more aware not only of their own feelings, thoughts, and motives but also of the emotions and mental states of others. Both social working memory and social cognition involve basic social cognitive/affective mechanisms and support social forms of attention, such as mutual attention and joint attention during social interaction and communication. The social-cognitive model of joint attention proposes that, as infants monitor and represent their own goal-related intentional activity, they also monitor and represent the goal-related behavior of others (Tomasello et. al., 2005).

In general, social working memory is involved when we attempt to navigate through a broad range of interpersonal interactions that we encounter on a

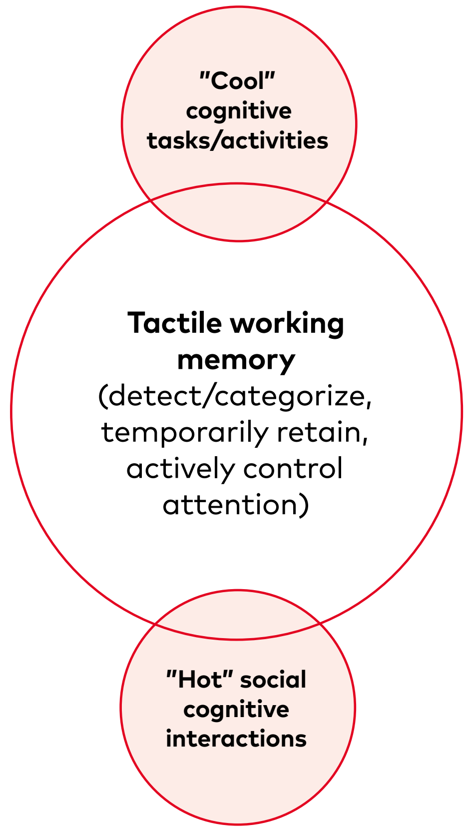


Figure 5. Tactile working memory involves three distinct processes (detect/categorize, temporarily retain, actively control attention) and supports "cool" cognitive and "hot "social cognitive processes.

daily basis. Social working memory interacts with the different components of social cognition and is engaged to manage the demands of social cognition.

The strategies for managing demands to social cognition and improving social working memory skills are broadly referred as **social cognitive strategies**. Furthermore, when implementing social cognitive strategies to enhance the quality of social working memory in persons with CDB, it is necessary that the interaction partner is sensitive to the person´s attention focus, fosters a sense of togetherness, supports the social forms of attention, provides scaffolding, stimulates reciprocity/turn-taking and establishes conversational practices in the bodily-tactile modality (see partner competencies 4.1.1). For individuals with CDB, shared touch and motion with their interaction partners are the primary means for attachment building, joint attention and communication (Nafstad & Rødbroe, 2015).

In summation, the key argument outlines that working memory in information processing is linked to perception and attention in a manner that it affects somatosensory processing. Working memory also supports the instant retrieval of stored information in long-term memory and the shifting, inhibiting and monitoring of somatosensory information. In view of this description, tactile working memory requires our ability to detect and categorize bodily-tactile information, temporarily retain the information, and actively control attention to produce a desired result during "cool" cognitive tasks/activities, such as problem-solving skills, reasoning abilities and language learning and "hot" social cognitive interactions such as understanding other people's behavior in terms of underlying mental states, evaluating our behavior in the moment and recognizing another person's point of view. See figure 5.

Perceptual

- **Perceptual strategies:** strategies to promote perceptual learning and to guide behavior.

Cognitive

- **Long-term working memory strategies:** strategies for enhancing the link between working memory and long-term memory.
- **Maintenace cognitive strategies:** strategies for enhancing working memory and learning.
- **Metacognitive strategies:** cognitive strategies for exercising attentional control and organizing learning.

Social cognitive

- **Social cognitive strategies:** strategies for keeping track of various amounts of social information, managing demands to social cognition and improving social working memory skill.

Figure 6. Classifications of learning strategies distinguish between perceptual, cognitive and social cognitive strategies, that learners use in order to learn or socially interact more successfully.

Accordingly, a learner will use different learning strategies (perceptual, cognitive, social cognitive) in order to gather information, attend, problem solve, remember, or socially interact more successfully. See figure 6.

2.1.3 Brain representations of the somatosensory processing system

The brain is only connected to the body and to the outside world through the sensory systems (Coren, Porac, & Ward, 1984). The following section examines the neural pathways and individual regions involved in the somatosensory processing system. In particular, we report on evidence from neuropsychology, neuroimaging, and neurophysiological experiments that have highlighted the crucial role played by the somatosensory processing system in mediating bodily-tactile information. Through the somatosensory processing system, the brain is able to communicate with the surrounding world.

The somatosensory processing system of persons with CDB could impaired due to nerve disruptions, brain malformations or epileptic seizures. Persons with deafblindness may also exhibit irregularities in somatosensory functions, such as displaying less interest (low-registering and insensitive) or trying to limit the sensory input they must deal with (tactile defensiveness). Besides, the somatosensory processing system of persons with CDB could be intact and function normally.

Accordingly, by having the knowledge of the basic concepts and the underlying neural dynamics of the somatosensory processing system will help us understand the specific disruptions, deficits, and irregularities. Besides, this knowledge will also give us the possibility to recognize potentials and discover personalized intervention strategies that support working memory functions in the bodily-tactile modality.

"The skin is an important sensory organ and is responsible for providing information about contact of the skin with objects in the external world."

Successful processing of complex somatosensory information relies on the interplay between low-level sensory processing (bottom-up processing) and higher-level cognitive processing (top-down processing). Bottom-up and top-down processes describe the two ends of a continuum that describes the relative weight of external environmental stimuli versus internal cognitive processes in interpreting somatosensory information (See figure 1, page 22). Accordingly, our brain should be conceived not only as a passive receiver of sensory information but also as an active predictor of incoming signals that consists of an elaborate network of activities that involves both bottom-up and top-down influences. The brain would continuously generate internal representations of future states in terms of short-term estimations of upcoming events, or long-term guesses about the likelihood of events in the very far future.

Bottom-up processing is any processing that starts at the sensory input and is largely a sensory-driven process (spontaneous attention). Top-down processing always begins with a person's previous knowledge, and forecasts due to this already acquired knowledge (Goldstein, 2011). In broad terms, this account is in line with the well-known principle that top-down processing becomes more important when a condition require a lot of attentional resources (effortful attention). Such top-down processing capacity permits our brains to analyze complex somatosensory information rapidly and allows us to add assumptions and supplemental information derived from past experience to the evidence of the sensory information.

The somatosensory processing system involves the basic somatosensory pathways and is divided into defined regions of the brain and distinct streams of information processing. The somatosensory system provides information to the brain about the state of the body and its contact with the world.

The organization of the somatosensory system is quite distinct from that of the other senses. In particular, other sensory systems have their receptors localized to a single organ, where they are present at high density (e.g., the eye for the visual system, the ear for the auditory system). In contrast, somato sensory receptors are distributed throughout the body. In addition, the other senses convey their information to the brain via a single nerve bundle, whereas

Table 1. The major classes of receptors, type of receptors and functions.

Major classes of receptors	Type of receptors	Functions
Mechanoreceptors	Meissner's corpuscles Pacinian corpuscles Merkel's disks Ruffini's corpuscles	Light touch, slow vibrations Rapid vibrations, deep pressure Sustained touch, pressure Skin stretch
Thermoreceptors	Krause end bulbs Ruffini endings Free nerve endings	Determining cold/warm sensations (temperature)
Nociceptors	Free nerve ending	Detecting pain sensations
Proprioceptors	Joint receptors Golgi tendon organs Muscle spindles	Joint position Muscle tension Muscle length
C-Tactile fibers	Unmyelinated afferent fibers	Slow gentle touches that respond to pleasant touch

somatosensory information from the skin, muscles and joints arrives to the brain via separate ascending pathways up the spinal cord.

The skin is an important sensory organ and is responsible for providing information about contact of the skin with objects in the external world. The skin has a huge network of nerve endings and receptors. A variety of sensory receptors, such as mechanoreceptors, thermoreceptors and nociceptors provide information to the brain about the state of the body. Furthermore, sensory receptors in the joints and muscles (proprioceptors) will bring about the sensations of joint position, muscle tension and muscle length. The various types of receptors, mechanoreceptors, thermoreceptors, nociceptors and proprioceptors work together to ensure that complex stimuli are transmitted properly to the brain for processing (see table 1).

The somatosensory system is a three-step neural system that

1. receives the multiple types of sensation,
2. conveys them via neural pathways through the spinal cord and brain stem (the stem-like part of the base of the brain; see figure 8, page 38) and
3. processes them in distinct areas or networks of the brain (Brodal, 1969).

In other words, the multiple types of sensation received from the surface or inside the body travel along different anatomical pathways in the spinal cord and has different targets in the brain depending on the information carried.

In outline, there are two major neural pathways in the spinal cord that carry inputs from the various types of receptors to the brain. For instance, light touch, vibration and proprioception are conveyed by the dorsal column-medial lemniscus pathway, whereas pain and temperature are conveyed by the ascending lateral spinothalamic tract.

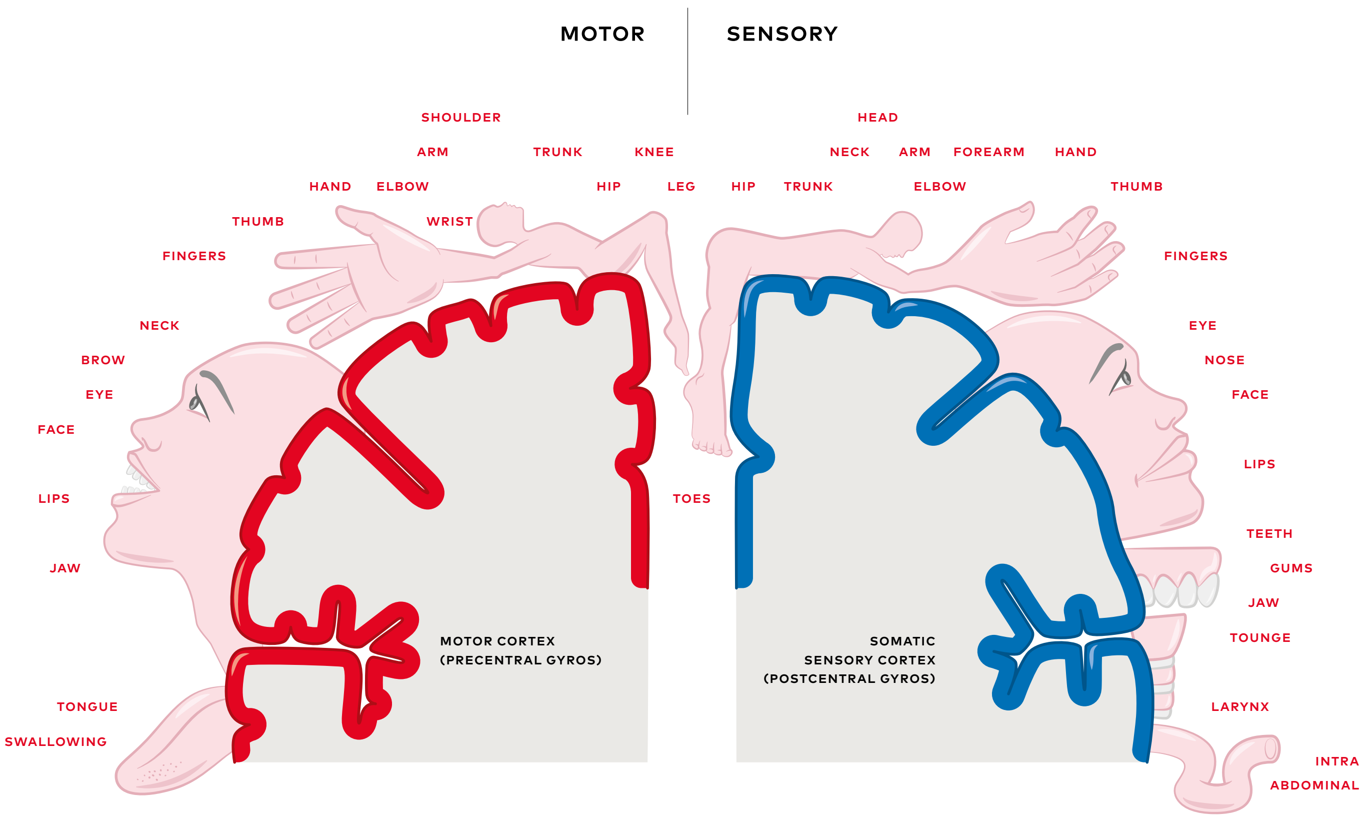


Figure 7. The somatosensory homunculus and the motor homunculus.

The primary somatosensory cortex in the parietal lobe (the middle division of each brain hemisphere) is the main sensory receptive area for the multiple types of sensation received from the surface or inside the body. It is the crucial brain structure responsible for processing the multiple types of sensation from the body. Information from the primary somatosensory cortex is then transferred to the secondary somatosensory cortex, which is adjacent to the primary somatosensory cortex.

Both primary somatosensory cortex and secondary cortical areas are responsible for processing the complex picture of stimuli transmitted from the interplay of receptors. A neuroimaging study has demonstrated that when we are involved in tactile-based tasks both the primary and secondary somatosensory brain areas are engaged (Plager, et al., 2003).

A prominent feature of the somatosensory cortex is its somatotopic organization, such that the body surface is mapped across the postcentral gyrus of the parietal lobe and corresponds point-for-point with the body´s topography. In other words, the foot is next to the leg which is next to the trunk which is next to the arm and the hand (neural body map).

These neural maps are dependent on the amount or importance of the somatosensory input they receive. For example, a relatively larger proportion of a neural body map is given over to the representation of the hands than to other parts of the body, given their relative surface area (e.g., Nakamura et al., 1998; Penfield & Boldrey, 1937). See figure 7; the somatosensory homunculus is in blue.

The neural body maps of the somatosensory cortex are an important part of how we build up an implicit sense of ourselves through the sense of having a body and feeling our body move. These neural maps are shaped by experience, especially when using active touch and motion in our environment.

The brain areas that are responsible to process motor information is called the motor cortex. Like the somatosensory cortex, the motor cortex is also somatotopic organized. (See figure 7 page 36: the motor homunculus is in red.) The three different areas of the motor cortex (primary motor cortex, premotor cortex, supplementary motor area), encode simple or complex patterns of motor output and select appropriate motor plans to achieve desired end results. For instance, the primary motor cortex is involved in simple movements, while the supplementary motor area is involved in complex movements and in the mental rehearsal of sequences of movements. There is a close relationship between the somatosensory and motor cortex. The close link between the organization of the somatosensory and the motor cortex is highlighted by the important relationship between the perception of touch on the hands and hand movements (Gallace & Spence, 2008; Gallace, & Spence, 2010).

Furthermore, the somatosensory cortex, the motor cortex, the brain stem, together with the cerebellum (tucked underneath the temporal and occipital lobes which regulates motor movements; see figure 8 page 38) allows us to plan and execute goal-directed movements.

There is some evidence suggesting that the somatosensory cortex is organized to have sophisticated social cognition abilities that allow us to reason about other people's internal states. For example, when participants were scanned while they saw a video of someone else being touched on the face (observed touch) or when they were touched on the same spot themselves (felt touch) the same region of the somatosensory cortex were activated (Blakemore et al., 2005). Furthermore, the differentiation between self-produced touch and touch by others (social touch) is necessary for successful social interactions in adults. A recent study demonstrated a robust self–other distinction in brain areas related to somatosensory and social cognitive processing. This study suggested that there is a difference as early as in the spinal cord in the processing of stimuli arising within the body and sensory perceptions from self-touch and those from touch by another person (Boehme, et. al., 2019).

Developmental studies have shown that the somatotopic organization emerge very early in human development. A research study on the somatotopic organization during tactile stimulation in infants provides evidence of neural body maps in 7-month old infants (Marshall & Meltzoff, 2015). The authors suggest that the development of neural body maps in the first months of life provide crucial information about how babies develop a sense of themselves as individuals and form their earliest social interaction with others. This result is in accordance with earlier studies that have suggested the presence of early tactile representations in infants, for instance, a study have demonstrated tactile memory in 8-month-old infants (Catherwood, 1993).

Similarly, a study on infant brain responses during felt touch (infants had their own hand or foot touched) and observed touch (infants observed some-

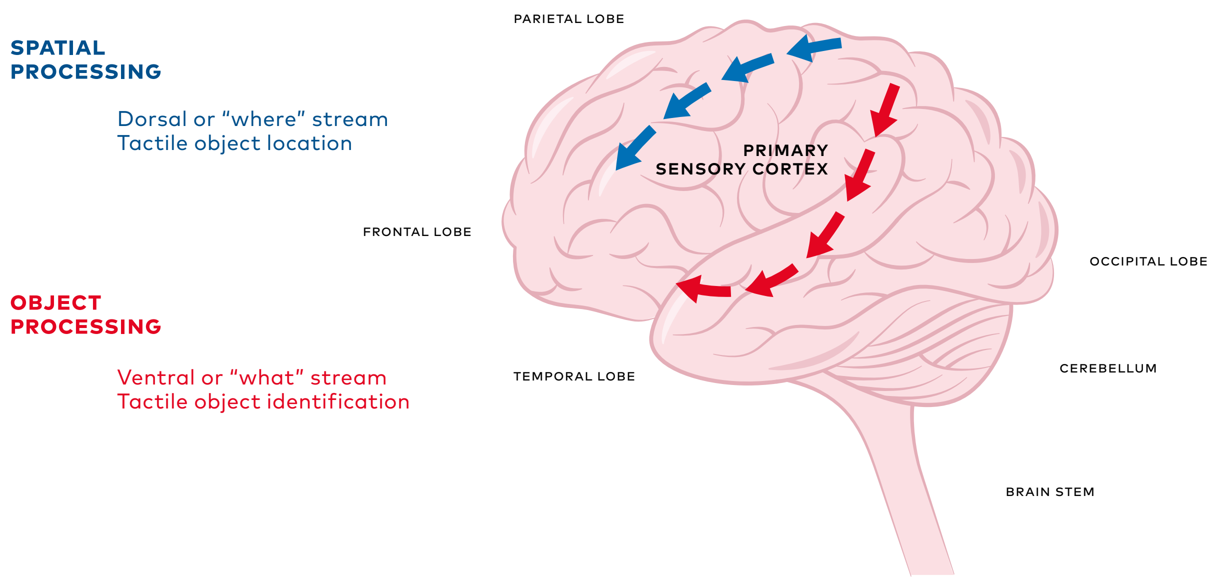


Figure 8. A dual pathway system comprising both a ventral stream responsible for tactile object identification ("what" pathway) and a dorsal stream responsible for tactile object location ("where pathway"). The four lobes of the cerebral cortex (frontal, parietal, temporal and occipital), the cerebellum and the brain stem are also illustrated.

one else's hand or foot being touched), showed different brain activation patterns. During felt touch the somatosensory cortex was activated, however during observed touch both the visual and the somatosensory cortex were significantly activated (Meltzoff, et al., 2018). This finding shed light on aspects of early social cognition through the bodily-tactile modality, including action imitation and empathy, which may build at least in part, on infant neural representations that map equivalences between the bodies of self and other.

There is a large and growing body of evidence that cortical networks for decoding what and where information are processed in separate (but highly interactive) processing streams in the brain. The somatosensory processing system is divided into distinct streams but act together with each other and with other brain areas at the same time. Reed and colleagues (2005) have suggested the segregation of tactile perceptual information processing to a dual pathway system comprising both a ventral stream (lower surface of the brain) responsible for tactile object identification and a dorsal stream (upper surface of the brain) responsible for tactile object location (Reed, Klatzky, & Halgren, 2005). The ventral stream is called the "what" pathway, whereas the dorsal stream is called the "where" pathway. In other words, the "what pathway" makes it possible to recognize objects, faces, facial expression, whilst the "where" pathway is responsible for recognizing the location or placement of an object for which spatial awareness is needed. See figure 8. This distinction between the memory for identification (what) and memory for position and location (where) of tactile stimuli seems to be similar to that reported previously for the processing of visual stimuli (Khader et. al., 2005; Mishkin, Uncerleiderl, & Macko, 1983) and of auditory stimuli (Rauschecker, 1998; Kraus & Nicol, 2005).

This dual memory system might also be, at least up to a certain point, lateralized in the human brain, with a prevalence of left hemisphere structures involved in the storage of tactile object structural characteristics and a predominance of right hemisphere structures involved in the storage of the tactile spatial aspects of the stimuli (Vallar, 2007; see also Gallace & Spence, 2009).

The studies investigating the neural basis of tactile working memory have demonstrated the involvement of the anterior areas of the brain (frontal-parietal network) during tactile spatial working memory tasks (Ricciardi, et al., 2006; Kostopoulos, Albanese, & Petrides, 2007). A frontal- parietal network was also involved in the executive control of tactile working memory (Gogulski, et. al., 2017). Similarly, frontal-parietal networks were recruited during spatial working memory tasks in both the tactile and visual modalities, suggesting that common brain regions may subserve the generation of higher order representations involved in working memory for both visual and tactile information (Ricciardi et al. 2006).

Regarding long-term memory processing the medial temporal lobe plays a central role. The medial temporal lobe includes a system of anatomically related structures that have been shown to play a role in different forms of learning and memory. Among these, the hippocampus (a seahorse-shaped brain structure within the temporal lobe) and the adjacent cortices, has been recognized as fundamental in the formation of both semantic and episodic memories (Kosslyn, 2007). Furthermore, it has been suggested that the storage and retrieval of tactile information in the long-term memory rely on structures of the medial temporal lobe (Bonda, et. al., 1996).

"There is a close relationship between the somatosensory and motor cortex."

Autobiographical memory, the personal memory for specific events or experiences in one's life, also involves the hippocampus and particularly the amygdala (an almond-shaped brain structure within the temporal lobe). The hippocampus is involved in connecting the memories of the different sensory-perceptual elements from the different sensory brain areas to form an episode, rather than remaining a collection of separate memories. The amygdala, on the other hand, is responsible for the subjective personal events that contain powerful emotional significance to stay part of our autobiographical memory. The hippocampus and amygdala are ideally situated to combine information about the cognitive and emotional areas and bind that information into a bodily-tactile memory trace that codes for all aspects of a personally experienced episode. The emergence of the bodily-tactile memory trace is closely linked to the concept of bodily emotional trace which is applied in the field of deafblindness. When an emotional experience or activity leaves a bodily sensory trace, this can

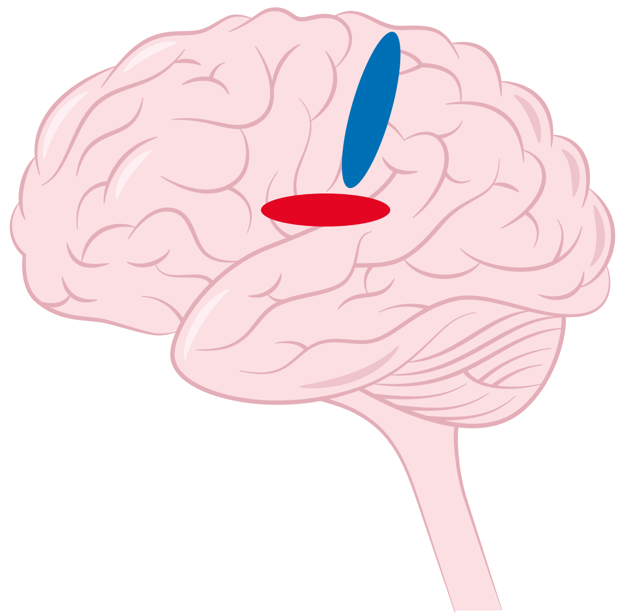


Figure 9. Illustration of the brain highlighting the insular cortex that is involved in pleasant touch (in red), and the somatosensory cortex that is involved in discriminative touch (in blue).

subsequently be expressed as a bodily emotional trace, localized in the body where it was sensed (Janssen & Rødbroe, 2007).

Furthermore, the hippocampus structures are also responsible for our spatial memory and has been shown to be involved in the brain system that maps self-location during navigation in the proximal environment (Høydal, et. al. 2019). Research has also demonstrated a role for hippocampal place cells in representation of the spatial environment in the brain (Moser, Kropff, & Moser, 2008). This is the brain's "inner GPS", which helps us navigate our way through a complex environment. These hippocampal cells play a significant role in spatial cognition. For example, superior spatial navigation performance in the blind has been correlated with a larger volume of the hippocampus, a structure with a well-established role in navigation and spatial memory (Burgess, Maguire, & O'Keefe, 2002).

Despite the dominance of vision and audition in human social communication, studies have shown that we can also reliably communicate emotions through tactile interactions (Hertenstein, et. al., 2006). Humans can tactually recognize facial expressions of emotion surprisingly well and a neuroimaging study has shown that tactile and visual facial expressions of emotion rely on distinct but overlapping neural substrates (Kitadaa, et al., 2010).

In recent times the neural mechanisms by which affective touch affects behavior in social interactions have been identified. Several studies indicate that specific neural fibers known as C-tactile afferents contribute to pleasant touch and activate the insula cortex in the brain (Olausson, et al., 2002: Löken, et. al., 2009; Perini, Olausson & Morrison, 2015; Liljencrantz & Olausson, 2014; Pawling, et. al., 2017). This would suggest that the neural substrate of pleasant and discriminative touch might be different. Discriminative touch involves the primary/secondary somatosensory cortex and in contrast pleasant touch involves the insula cortex. See figure 9 page 40.

"In summary, the brain internally emulates the surrounding environment through networked brain activity by way of multiple types of sensations from the body."

The insula cortex in the brain receives sensory inputs via the thalamus and sends outputs to several structures associated with the limbic system, such as the amygdala, and the orbitofrontal cortex and it has been convincingly shown to be associated with several basic emotions such as anger, fear, disgust, joy, and sadness, as well as with pain processes (Wager, 2002). There is evidence suggesting that gently stroking babies activates C-tactile afferents and reduces the activity in the infant brain associated with painful experiences (Gurus, et. al., 2018). Thus, the insula appears to provide an emotional context that is suitable for a given bodily-tactile experience and it tends to strengthen the case for the insula's likely role in the way we represent our bodies to ourselves and in the subjective aspect of emotional experience. In particular, the insula plays an important role in supporting certain aspects of the body schema. Body schema which is the personal awareness of one's body, including the location orientation and motion of its various parts has tactile, proprioceptive, and kinetics aspects (Gallace & Spence 2010).

Moreover, brain imaging research suggests that working memory for task-relevant information (cognitive working memory) and working memory in social contexts (social working memory) may rely on distinct, though perhaps correlated, brain mechanisms. For example, results from a functional magnetic resonance brain imaging (fMRI) study demonstrated that the lateral frontoparietal system supported the cognitive demands that are needed for task performance (cognitive working memory) and in contrast, the medial frontoparietal system uniquely supported social cognitive processes in working memory (social working memory) (Meyer, Taylor, & Lieberman, 2015).

In summary, the brain internally emulates the surrounding environment through networked brain activity by way of multiple types of sensations from the body. Although specific neural pathways and individual regions are involved in the somatosensory processing system, it is important not to merely understand the individual regions but to understand the connections among all the regions of the brain (functional brain connectome). Functional brain connectome is about how each region is functionally connected to every other region of the brain and how it is shaped by learning and experience (Talukdar, et. al., 2018). The somatosensory system responds flexibly to the environment at multiple levels of processing and functions differently across situations as well as people.

2.1.4 Is the somatosensory system capable of neuroplasticity?

The human brain is a malleable organ that responds to the environments we are placed in and the challenges we face. It is considered to be a highly dynamic and a constantly reorganizing system capable of being shaped and reshaped across an entire lifespan. The lifelong capacity of the brain to change and rewire itself in response to the stimulation of learning and experience is known as neuroplasticity.

Several studies have shown that the somatosensory cortex is clearly capable of neuroplasticity due to intense haptic/tactile training or expertise. For instance, a neuroimaging study has shown that long-term training in tactile discrimination modified the tactile-to-visual cross-modal responses and plasticity in the primary visual cortex of normal subjects (Daisuke, Tomohisa, & Manabu, 2006; Saito, et. al., 2007).

However, neuroplasticity changes in the somatosensory cortex may also occur as a result of disorders or deprivation. For instance, a neuroimaging study on people born with one hand (congenital one-handers) indicated that the missing hand area in the somatosensory cortex is functionally modified to support other body parts, including the arm, foot, and mouth (Hahamy, et al., 2017). Furthermore, neuroplasticity following sensory deprivation has als been demonstrated. For instance, expansion and reorganization of the cortical finger representation in the somatosensory cortex has been reported in blind proficient Braille readers (Sterr, et al. 1998; Burton, et al., 2004). Likewise, a neuroimaging study has shown experience-dependent neural plasticity in the somatosensory cortex of people with blindness (Wong, Gnanakumaran, & Goldreich, 2011).

Interestingly, knowledge of how tactile-based language is processed in the brain has not only furthered our understanding of the brain itself but has also played a part in quashing the notion that these bodily-tactile signs are simply a loose collection of bodily gestures strung together to communicate spoken language. A neuroimaging study has shown that a tactile-based language activated brain areas similar to spoken language in an acquired deafblind subject (Osaki, et al., 2004). Similarly, a fMRI brain imaging study found that in the case of combined early onset visual and auditory sensory deprivation, tactile based communication was associated with an extensive cortical network implicating occipital as well as posterior superior temporal and frontal associated language areas (Obretenova, et. al., 2010). These two studies may be suggesting that (a) the same neural architecture is involved in spoken and tactile based language; (b) the brain structure for language develops in response to language input regardless of the modality of that input.

"The human brain is considered to be a highly dynamic and constantly reorganizing system capable of being shaped and reshaped across an entire lifespan."

2

Some studies have focused on tactile cognitive functioning in persons with deafblindness. A study that compared the performance of deafblind individuals with sighted-hearing participants on four tactile memory tasks showed that the deafblind participants took less time and made fewer attempts than the sighted-hearing participants to feel and remember the target stimuli (Arnold & Heiron, 2002). Although, the deafblind participants did not necessarily perform any more accurately than the sighted-hearing participants, they performed more rapidly. The explanation given for the rapid tactual processing speed of the persons with deafblindness was that it was a product of more tactual experience. Cognitive processing speed when defined as the ability to process information rapidly, is closely related to the ability to perform higher-order cognitive tasks (Lichtenberger & Kaufman, 2012). Furthermore, a study that compared the performance of individuals with deafblindness on working memory capacity tasks in the different sensory modalities (visual, auditory, tactile), found that the group with deafblindness performed better on the tactile than on the visual and auditory working memory span tests. This study suggested that the poor performance by the persons with deafblindness on the visual and auditory working memory tasks was a result of the dual sensory impairment (Nicholas, 2010). Likewise, individuals with dual sensory loss performed significantly better on a tactile test battery than individuals with dual sensory loss diagnosed with dementia (Bruhn & Dammeyer, 2018).

Brain reorganization associated with altered sensory experience clarifies the critical role of neuroplasticity in development. Regarding persons with congenital deafblindness, an electrophysiological study found significant change in the somatosensory brain area of children with congenital deafblindness in comparison to a control group of seeing and hearing children (Charroó-Ruíz, et al., 2012). The authors suggest that a possible interpretation of this finding could be that with simultaneous loss of hearing and vision at very early stages of neural development, the sense of touch acquires a more important role in children's communication with their surroundings. These results give evidence of neuroplasticity in deafblind children that seem to be closely related to the intensive use of their body and hands to interact with people and their environment.

Taken together, these studies demonstrate that the somatosensory system retains a high degree of neuroplasticity, which can occur with increased experience within the bodily-tactile modality. Furthermore, it could be suggested that by providing individuals deprived of both vision and hearing with experience driven learning strategies (perceptual, cognitive and social cognitive) within the bodily-tactile modality may help their brains reorganize for more enhanced processing and efficient bodily-tactile abilities.

2.2 Understanding the development of tactile working memory through transactions

Although the cognitive information-processing approach to working memory mainly focuses on internal mental process that allows us to handle representations of our immediate environment, it is necessary to point out the complex interplay between individual, relationship, cultural and societal factors in shaping tactile working memory. A transactional model understands development as a transaction or exchange between person and environment. Behavior, in general, and development, in particular, cannot be separated from the social context (Sameroff, 2010).

According to the transactional approach, working memory should be considered as a dynamic process, characterized by unique individual features predominantly facilitated through social interactions and affected by multiple levels of the surrounding environment. Subsequently, the term working memory in this point of view refers to the mental effort expanded in processing information held in mind through transactions, which involve the dynamic interplay between the person and his/her physical and social surroundings. This is termed as the transactional model of working memory.

The fundamental assumption of the transactional model of working memory is that development is facilitated by a bidirectional, reciprocal interaction between the person and his/her environment. A change in the person may trigger a change in the environment, which in turn affects the person and so on. In this way, both the person and the environment change over time and affect each other in a reciprocal fashion, and early achievements pave the way for subsequent development. This model is influenced by Sameroff and colleagues' transactional model of development (e.g., (Sameroff & Chandler, 1975; Sameroff & Fiese, 2000)).

According to the transactional model of working memory, transactions arise centered around the interface of the deafblind person and his/her interaction partner. The person is viewed as an active participant who learns to affect the cognitions and social cognitions of others and who gradually learns to use more sophisticated and conventional means to communicate through the partner´s contingent social responsiveness. The quality and nature of the contexts in which exploration or interaction occurs are considered to have a great influence on the development of working memory.

The transactional model describes working memory as an ongoing process in which the interaction partner optimizes the physical and social environment. Additionally, the interaction partner generates social realities within social and

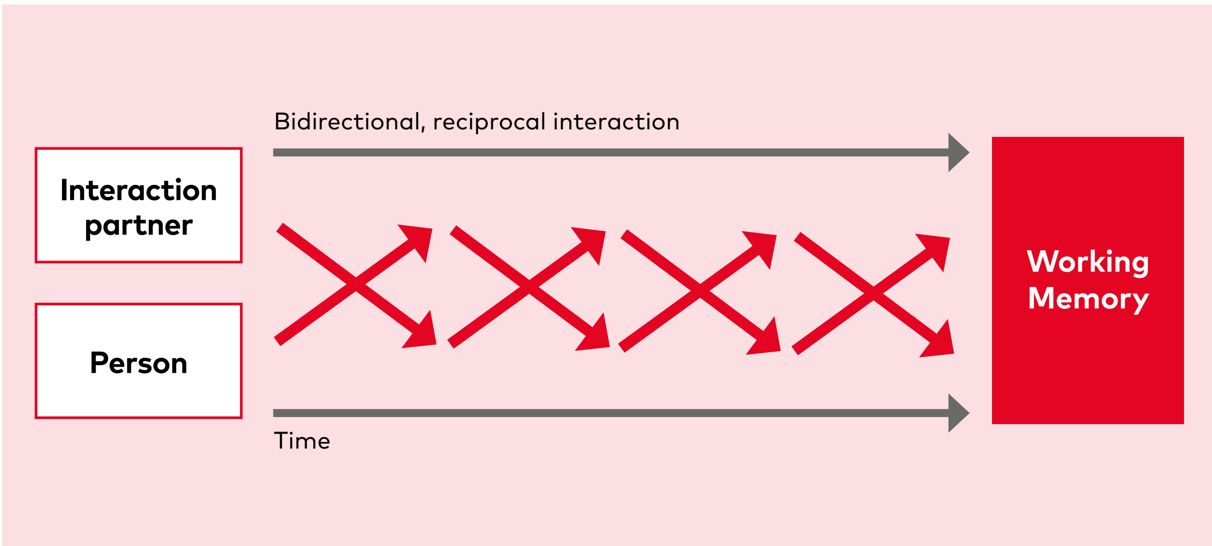


Figure 10. The development of working memory through transactions: The quality and nature of the contexts in which interaction occurs are considered to have a great influence on the development of working memory.

relational contexts based on interactions within a bodily-tactile modality. This perspective emphasizes the reciprocal, bidirectional influence of the communication environment, the responsiveness of interaction partners, and the person's own developing competence.

The transactional model conceptualizes the development of working memory as a function of bidirectional and reciprocal exchanges between the person and the interaction partner over time. It emphasizes that the development of working memory must be seen in the relationship between the individual and the context, and not only in an individual himself. See figure 10.

2.3 Understanding tactile working memory within the dynamic assessment approach

Conventional assessment of working memory encompasses a range of standardized tests, such as the digit span, spatial span and n-Back tasks to valid questionnaires, such as the Behavior Rating Inventory of Executive Function (Gioia, Isquith, Guy, & Kenworth, 2000), Working Memory Rating Scale (Alloway, Gathercole, & Kirkwood, 2008) and The Working Memory Questionnaire (Vallat-Azouvi, Pradat-Diehl, & Azouvi, 2012). The conventional assessment generally refers to a standardized testing procedure in which an examiner presents items to an examinee without any attempt to intervene, guide, or improve the individual's performance within the test situation.

In contrast, to a standardized testing a dynamic assessment refers to an assessment through an intervention process which is aimed at modifying an individual's cognitive functioning and observing subsequent changes in learning and problem-solving patterns within the assessment process. Dynamic assessment focuses on the support that an individual requires to successfully perform a task rather than on the level of difficulty at which performance breaks down.

Dynamic assessment is an umbrella term used to describe a heterogeneous range of approaches whose core is in blending instruction into assessment (Grigorenko, 2009). Several models of dynamic assessment have been suggested. They include (1) the amount of change demonstrated by a person on a given task in response to intervention (Budoff & Corman, 1976), (2) determining the amount of mediation needed to bring the person to a specific level of competence (Resing, 1993), (3) identifying inhibiting factors in the learning process of an individual and to determine promising interventions (Bosma & Resing, 2006). Although these dynamic assessment approaches may differ, they all highlight the general principle that guided learning can make a valuable contribution to the assessment process (Asha & Edvard, 1993).

Particularly, dynamic assessment relates to the assessment of learning potentials and focuses on the ability of the learner to respond to intervention. Dynamic assessment has been advocated as an interactive approach to conducting assessments as it can differentiate learning or cognitive potentials at the finer grained level. A dynamic model of assessment is capable of determining the structure of functions on a person-by-person basis (within-subject effects) (Fernandez, Fisher, & Chi, 2017). In other words, a within-subject-effect in dynamic assessment is a measure of how much an individual tends to change over time due to respond to intervention within the assessment process.

Dynamic assessment and its core are rooted in the notion of cognitive modifiability. Dynamic assessment of cognition is a diagnostic approach in which specific interventions are integrated into assessment procedures to estimate cognitive modifiability (Wiedl, Schottke, & Calero-Garcia, 2001). According to this perspective, working memory abilities must not be considered as stable traits, rather they are the result of an individual's history of social interactions in the world. Through participation in various activities, and through being guided or mediated by those around us, we come to master our working memory challenges in unique ways.

"Dynamic assessment and its core are rooted in the notion of cognitive modifiability."

In dynamic assessment, a specific form of assistance or mediation is provided, and this is the essence of the assessment process. (a) Lev Vygotsky's concept of a zone of proximal development and (b) Reuben Feuerstein's theory of mediated learning experience served as the main conceptual bases for most of the dynamic assessment elaboration.

a) The zone of proximal development is defined as the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). In other words, individuals can be supported by others to develop skills that are at a level just above their current developmental level. This type of support is referred to as scaffolding (Stone, 1998).

In a dynamic assessment context, this means that scaffolding is given by an interaction partner during the assessment not just to facilitate social relationships, but also to foster working memory by mediating effective learning strategies during the interactions. This type of scaffolding that emphasizes the mediation of individual learning strategies is referred as cognitive scaffolding (Park, & Reuter-Lorenz, 2009). Cognitive scaffolding is a dynamic process in which with the interaction partner who attempts to understand from the person´s responses what cognitive strategies are needed, and accordingly provide guided support to enhance cognitive functions.

b) Feuerstein describes the mediated learning experience as a process through which environmental stimuli do not impact directly on the organism but are filtered through some other person, usually an adult mediator, who selects, frames, modifies, and imposes order on the stimuli to ensure that 'the relations between certain stimuli will be experienced in a certain way' (Feuerstein, Rand, & Rynders, 1988). In a dynamic assessment context, this means that the examiner mediates the strategies for solving specific problems on an individual basis and assesses the level of internalization of these strategies as well as their transfer value to other problems of increased level of complexity, novelty, and abstraction.

Dynamic assessment is a method of conducting assessment which seeks to identify the learning or cognitive potentials that an individual possesses. The dynamic assessment approach emphasizes on the learning or cognitive potentials and accounts for the amount and nature of the mediator investment. It is highly interactive and process oriented. Generally defined as "an interactive, test – intervene – retest model of psychological and psychoeducational assessment" (Haywood & Lidz, 2007), dynamic assessment links assessment with intervention, and is viewed as an approach that enables examiners to move beyond merely testing current levels of performance (Boers, et. al., 2013). The great value of dynamic assessment lies in the fact that it has some capacity to reveal barriers to better learning and performance, the kind of assistance required to improve performance, the response to intervention, and the investment required to promote long-term gains in performance (Haywood & Lidz, 2007).

As follows, a dynamic assessment approach attempts to link a stepwise assessment with interventions, while enabling examiners to assess an indi-

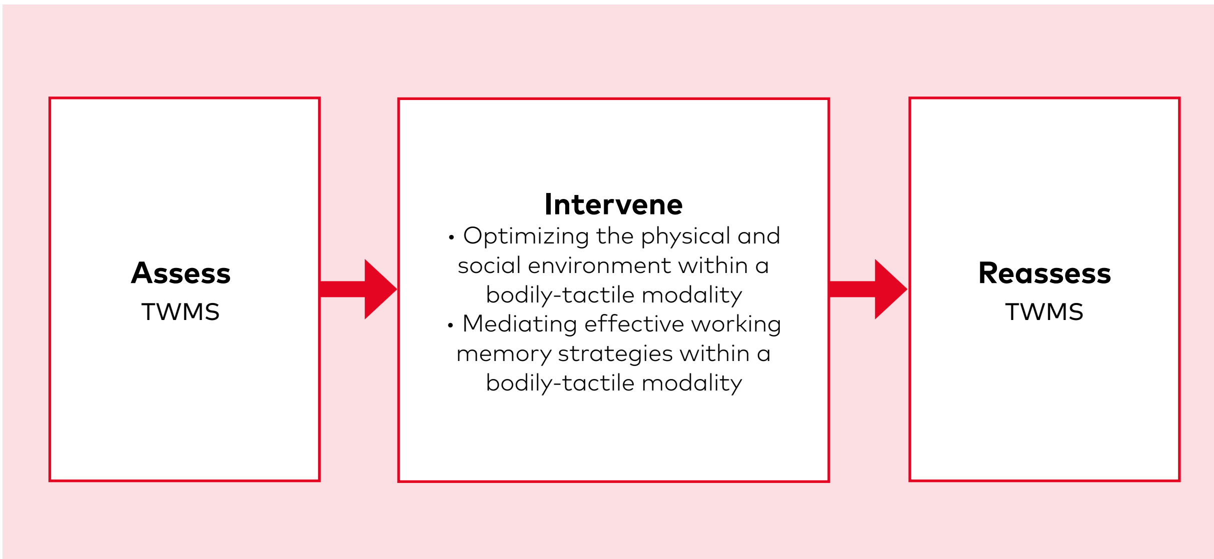


Figure 11. An interactive, Assess – Intervene – Reassess (AIR) model of tactile working memory assessment using the TWMS. During the intervention phase the person with deafblindness is offered physical, social and learning strategy mediation by a more capable interaction partner.

vidual's potential for learning or cognitive modifiability within the assessment. Accordingly, a tactile working memory assessment based on a dynamic assessment approach attempts to focus on the working memory potentials or capabilities of a person in respond to interventions. Cognitive potentials of children with special educational needs are better captured through tests administered in an assisted, scaffolded manner (Grigorenko, 2009).

The essence of assessing tactile working memory applying a dynamic assessment approach is that a person who is deafblind might perform above the limits of their optimal level of performance, when supported by an interaction partner who is able to facilitate social interactions and mediate individualized working memory strategies within the assessment. The assessment of learning /cognitive potential is the nucleus of dynamic assessment.

The sole use of standardized assessment instruments is inappropriate for children who are deafblind (Nelson, et. al., 2009; Silberman et al., 2004). This is because standardized instruments seldom include children who are deafblind as a norming group. In addition, standardized instruments require precise administration procedures that may not allow enough flexibility to accommodate the needs during the assessment process (Bruce, et. al., 2018). Contrarily, dynamic assessments are critical to capturing a complete understanding of the competencies and potentials of persons who are deafblind. Hence, assessment of people who are congenital deafblind should be carried out as a part of intervention (i.e., being assisted or dynamic in nature) and for the sake of selecting or modifying intervention.

The **Assess** – **Intervene** – **Reassess** (AIR) model of tactile working memory considers the interaction and the learning context. The AIR model includes both assessment and intervention, thus overcoming the disconnect between the assessor and the instructor and between assessment and teaching. See figure 11.

2.4 Understanding tactile working memory within an ecological assessment approach

2

People with deafblindness are better served when assessment and intervention are conceptualized within an ecological assessment perspective than within the traditional deficit model perspective. The deficit method conceptualizes problems as within the person, and the major consequence of this approach is that little time is spent analyzing the learning environment or other systems that might impact the person's competencies and potentials in their everyday life. In contrast, ecological assessment is an asset-based approach that considers the person's competencies and potentials, as well as the systems within which he/she interacts, when assessing and intervening (D'Amato et. al., 2005).

An ecological assessment is a comprehensive process in which information is collected about how the individual functions in different environments or settings. The ecological approach to assessment can help determine why the individual functions differently in different settings and with different people. Ecological assessments seem to better reflect everyday situations, the complexity of which cannot be reduced to a series of cognitive tests. Tests may deconstruct cognitive function precisely but lack the ecological validity of behavioral questionnaires (Egeland, et al., 2017).

Information for an ecological assessment is often obtained through observation in everyday functioning. An ecological assessment implies examining the individual's naturally occurring behavior, the environment immediately surrounding the behavior, and the individual-environment link.

The type of information collected in an ecological assessment includes information about (1) the physical and social environment, (2) interactions between the individual and his/her interaction partner and (3) patterns of behavior and activity during the interactions that are encountered on a daily basis.

The essence of assessing tactile working memory applying an ecological assessment approach is to identify the behaviors of the person with deafblindness which are appropriately related to working memory functions from less structured and more naturalistic learning situations. Many children who are deafblind function differently across environments. Thus, effective assessments are conducted across multiple and natural environments, with input from multiple adults (Chen et. al., 2009).

In summary, the above-mentioned theories and approaches should be considered as the fundamental principles when assessing tactile working memory in people with CDB.

Briefly, the fundamental principles are:

a) Applying the cognitive information processing theory and the functions of somatosensory processing system as a framework for identifying tactile working memory behaviors during tasks, activities and interpersonal interactions.
b) Understanding the development of tactile working memory through transactions. In other words, the development of tactile working memory should be seen as a function of bidirectional and reciprocal exchanges between the person and the interaction partner over time.
c) Understanding tactile working memory within the dynamic assessment approach. In other words, focusing on the tactile working memory potentials of the person in respond to interventions.
d) Understanding tactile working memory within an ecological assessment approach. In other words, emphasizing on an asset-based assessment that considers the tactile working memory potentials of the person in naturalistic learning situations

Chapter 3

The Tactile Working Memory Scale (TWMS)

THE TACTILE WORKING MEMORY SCALE (TWMS)

The TWMS is an itemized rating scale for assessing working memory in the bodily-tactile modality, identified by patterns of observable behavior in the everyday occurrences (activities/tasks) and during interpersonal interactions.

The TWMS has been developed for professionals to facilitate identification and promote effective interventions of working memory in the bodily-tactile modality, especially for people with CDB or with brain related visual and hearing loss. Particularly, the TWMS is a tool for enhancing the effectiveness of bodily-tactile working memory, with respect to the individual vulnerabilities, competencies and potentials.

Although the scale is developed for assessing working memory potentials in persons with CDB, it is feasible to use the TWMS for people with other disabilities who have difficulties using their vision and hearing effectively and who require bodily-tactile information for communication or cognitive development. For instance, the scale could be used to target interventions designed to help teachers support children with complex communication support needs.

It is highly recommended that the assessment using the TWMS is conducted on principles based on transactional, dynamic and ecological approaches, which may allow us to capture working memory potentials and developing learning strategies that are not always picked up on standardized assessments. See figure 12.

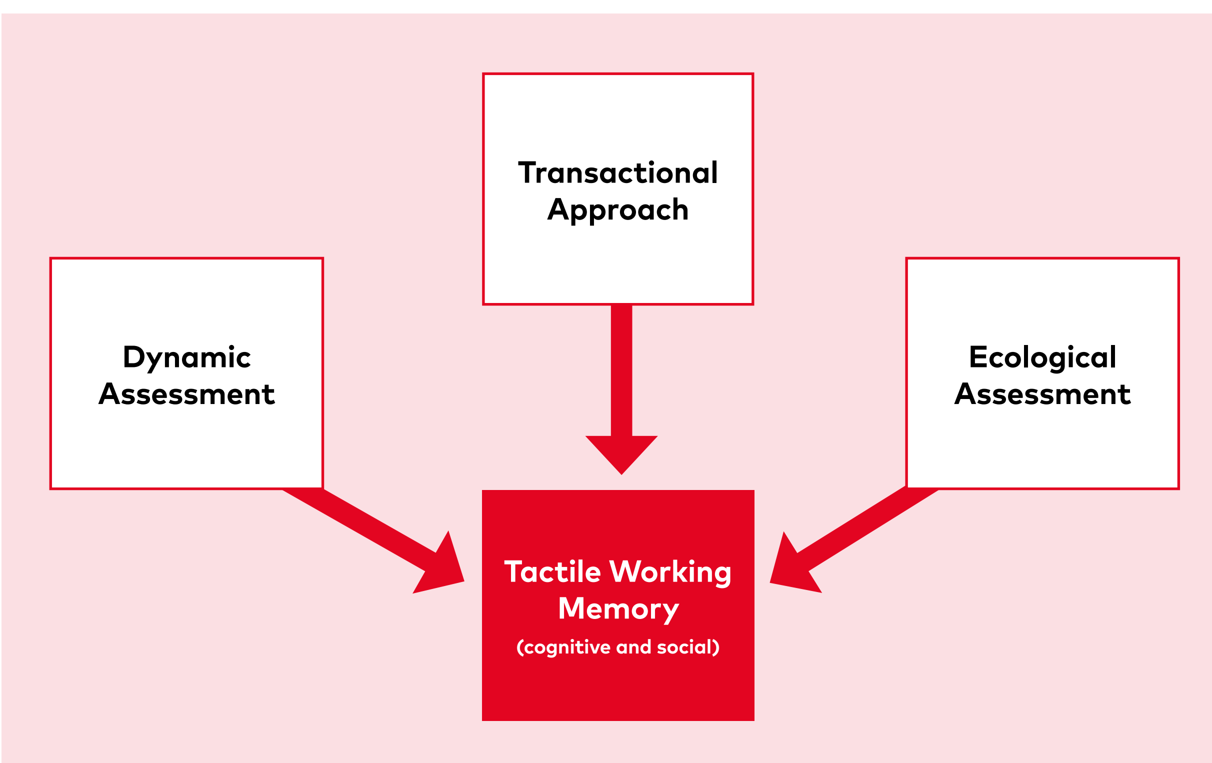


Figure 12. The transactional, dynamic assessent & ecological assessment approaches provide a basis to capture the functional aspects of tactile working memory.

3.1 Development of the TWMS

At the outset, the goal was to develop a measure of working memory functions in the bodily-tactile modality that would yield practically useful information about working memory potentials in people with CDB. The scale should adequately sample behavioral manifestations of working memory functions in a clear and coherent manner, such that professionals familiar with the construct could identify items and their respective domains.

The main purpose of the TWMS assessment is to obtain a high level of working memory functions in an individual by optimizing the physical and social environment of the person and by mediating effective learning strategies within the assessment. Importantly, this is in accordance with the social model of disability, which describes that disability occurs due to an uneven relationship between the individual's abilities and the construction of the physical/social environment or its requirements for ability. (UN General Assembly, Convention on the Rights of Persons with Disabilities, 2006).

3

"Particularly, the TWMS is a tool for enhancing the effectiveness of bodily-tactile working memory, with respect to the individual vulnerabilities, competencies and potentials."

Furthermore, the assessment can help us identify the level of understanding in the learning strategies as well as their transfer value to other activities/tasks of increased level of complexity or novelty.

To promote construct validity, the domains, subscales and items of tactile working memory were identified and conceptualized based on theory, clinical practice and research literature.

Research suggests that the concept of working memory not only refers to short-term storage of information, but also to perception, attention, executive control and is reciprocally linked to long term memory (Miyake & Shah, 1999). Furthermore, it involves a great deal of social cognitive processing and engages social working memory (Meyer, Taylor, & Lieberman, 2015).

The TWMS has been formulated in three steps: the first step was a literature review focusing on studies addressing cognitive information processing theory and the somatosensory processing system (i.e., Gallace & Spence, 2009; Song & Francis, 2013; Katus, Müller, & Eimer, 2015) and on clinical studies addressing tactile cognitions in neuropsychological test batteries (i.e., Halstead, 1947; Reitan, 1985; Decker, 2010).

The second step was to take into account the theoretical models of working memory (i.e., Baddeley & Hitch, 1975; Miyake, et al., 2000; Baddeley, 2003; Cowan, 2008 , Bouchacourt & Buschman, 2019); the theoretical models of tactile working memory (Bliss & Hämäläinen, 2005; Bonino, et al., 2008; Savini, et.al., 2012) and a theoretical model of tactile spatial model of working memory (Cohen, et. al., 2011). The tactile spatial model of working memory especially takes into account the crucial role of tactile experience in shaping working memory. During the second step particular emphasis was given to two specific working memory models: the model as suggested by Daryl Fougnie: working memory is the ability to retain information in an accessible state and includes the distinct processes of encoding, maintenance and manipulation of information (Fougnie, 2008) and the model of social working memory given by Meghan Meyer and Matthew Lieberman: social working memory is working memory for social cognitive information and includes the mental processes of accessing, maintaining and manipulating of social information (Meyer & Lieberman, 2012).

During the third step the items within the working memory domains (encoding/accessing, maintaining and manipulating information/social cognitive information) were selected from behavioral observations in the everyday occurrences (activities/tasks) and during interpersonal interactions between people with CDB and their interaction partner(s). Based on the scientific literature, clinical experience and video analysis 25 items were initially generated to identify the three tactile working memory domains.

Furthermore, collaboration was sought with professionals who work with people with deafblindness in the following professional institutes: (1) professionals in deafblindness at Statped national service for special needs education in Norway; (2) members of the multidisciplinary diagnostic team on deafblindness of the Royal Dutch Kentalis in the Netherlands; (3) teachers at the Rafaël School for the deafblind of Royal Dutch Kentalis in Sint-Michelsgestel in the Netherlands.

Several cases with people with deafblindness (n=14) were analyzed by the professionals to identify tactile working memory behaviors on the items. To ensure consensus the professionals were asked to rate each item on four response choices (present, emerge, absent, not applicable). Five out of the 25 items were deleted because they could not be clarified without significantly altering the underlying meaning.

A first trail of the scale was made, and the final 20 items scale was used as a starting point for a small-scale preliminary study (n=4). This study resulted in the current version of the Tactile Working Memory Scale (TWMS). The 20 items of the scale are abstract and theoretical but have been observed in practice. Furthermore, a study using video observation and analysis in a person with CDB was able to identify tactile working memory behaviors on the items of the TWMS (Tunes, 2018).

The form of the TWMS contains 20 items within 3 theoretically derived domains that measure the different processes of tactile working memory; ENCODE (detection and initial interpretation), MAINTAIN (temporarily retaining) & MANIPULATE (actively controlling attention) bodily-tactile information during everyday occurrences (activities/tasks) and during interpersonal interactions.

Table 2. The three different working memory processes and the number of items.

Working memory domains	Number of items (n=20)
ENCODE detection and initial interpretation	6
MAINTAIN temporarily retaining	7
MANIPULATE actively controlling attention	7

3

Table 2 shows the description of the three different working memory domains and the number of items within the three domains.

Table 3 shows the 20 items, the behavioral descriptions and the domains of the TWMS.

3.2 TWMS materials and scoring procedures

The TWMS materials consist of the TWMS form and the Scoring summary/profile form.

The cover page of the TWMS form includes instructions for completing the form. The second page contains an area for recording the date of assessment, general information about the person (name, age, gender), specific information about the person's sensory functions (vision, hearing), whether the person displays signs of tactile defensiveness, motor functions (gross and fine motor functions), and balance and coordination.

Tactile defensiveness is described as a negative reaction or sensitivity to touch. Tactile defensiveness can result in a tendency to be fearful, cautious, difficulty to engage and may prevent the individual to utilize active touch and motion to access information in an appropriate way.

The remaining three pages of the form are followed by the 20 items of TWMS with examples and response choices.

The rating of items on the TWMS consists of the following response choices; "present", "emergent", "absent", "not applicable". Table 4 shows scoring of the response choices (P, E, A or N/A) on the scoring form.

The Scoring summary/profile form provides information for hand-scoring the TWMS response choices (Table 5), as well as a graph for plotting the response choices to visually portray the person's working memory profile in relation to each individual item (Table 6).

Table 5 shows scoring of the response choices (P, E, A or N/A) on the scoring form.

Table 3. The 20 items, the subscales, the behavioral descriptions and the domains, of the TWMS.

Items	Behavioral descriptions	Domains
1) Uses active touch and motion to direct focus of attention towards an object of interest	Tactile focused attention	**ENCODE**
2) Uses active touch and motion in systematic exploration of an object of interest	Object manipulation (ventral stream function)	**ENCODE**
3) Uses active touch and motion to identify similarities or differences among objects	Tactile object identification: similarities/differences; classifying/categorizing (ventral stream function)	**ENCODE**
4) Uses active touch and motion in a purposeful manner to recognize objects in the vicinity	Tactile object recognition; retaining task-relevant information (ventral stream function)	**MAINTAIN**
5) Uses active touch and motion to identify an object in the immediate surrounding	Tactile object location (dorsal stream function)	**ENCODE**
6) Uses active touch and motion to locate a place when navigating within an environment	Tactile spatial reasoning: spatial navigation	**ENCODE**
7) Uses active touch and motion in a purposeful manner to recognize spatial relations among objects and locations	Tactile spatial recognition: retaining task-relevant information (dorsal stream function)	**MAINTAIN**
8) Uses active touch and body movements to intentionally explore and interact with the interaction partner during close bodily contact	Social working memory: person oriented	**ENCODE**
9) Uses active touch and motion to capture the emotionally triggered bodily signals or reactions of the partner	Social working memory: emotion perception	**MANIPULATE**
10) Uses active touch and motion to explore an object together with the interaction partner while displaying behaviors of social attention	Social working memory – mutual and joint attention	**MAINTAIN**

Items	Behavioral descriptions	Domains
11) Uses active touch and motion in a purposeful manner to recognize the partner, during the interaction	Social working memory: retaining social information	**MAINTAIN**
12) Uses active touch and motion to stay focused on a specific task or activity for a prolonged time	Tactile sustained attention	**MAINTAIN**
13) Uses active touch and motion to pay attention on the relevant details of a task or activity while filtering out distractions/ ignoring interruptions	Tactile selective attention	**MANIPULATE**
14) Uses active touch and motion to shift the focus of attention back and forth between different tasks or activities	Attentional switching	**MANIPULATE**
15) Stays focused on the interaction for a prolonged time	Sustained attention: interaction-time	**MAINTAIN**
16) Stays focused on the interaction when an unfamiliar/novel feature is introduced	Selective attention: interaction-novel condition	**MAINTAIN**
17) Stays focused on the interaction when an unfamiliar/novel feature is introduced	Attentional switching: interaction-topic change	**MANIPULATE**
18) Maintains information of specific episodes from the past in the present, especially when partner-guided long-term working memory strategies are provided	Attention manipulation: initiating long-term working memory strategies	**MANIPULATE**
19) Maintains information in the present and holds on to the information long enough to use it, especially when partner-guided maintenance cognitive strategies are provided	Attention manipulation: initiating maintenance cognitive strategies	**MANIPULATE**
20) Maintains information in the present and actively monitors or makes changes within his/her own learning, when partner-guided metacognitive strategies are provided	Attention manipulation: initiating metacognitive strategies	**MANIPULATE**

Table 4. Response choices and the descriptions.

Response choices	Response choices
Present (P)	when you can clearly observe the behavioral cues relevant to the item
Emergent (E)	when you can to a certain degree observe the behavioral cues relevant to the item: partially present
Absent (A)	when you cannot observe any of the behavioral cues relevant to the item
Not Applicable (N/A)	when an item doesn't apply in the current situation, due to relevant individual factors such as severe motor or physical limitation or other situational factors

Table 5. Scoring of the response choices.

Response choices	Scoring			
1) Tactile focused attention	P	E	A	N/A
2) Object manipulation (ventral stream function)	P	E	A	N/A
3) Tactile object identification: similarities/differences; classifying/ categorizing (ventral stream function)	P	E	A	N/A
4) Tactile object recognition; retaining task – relevant information (ventral stream function)	P	E	A	N/A
5) Tactile object location (dorsal stream function)	P	E	A	N/A
6) Tactile spatial reasoning: spatial navigation (dorsal stream function)	P	E	A	N/A
7) Tactile spatial recognition: retaining task – relevant information (dorsal stream function)	P	E	A	N/A
8) Social working memory – person oriented	P	E	A	N/A
9) Social working memory – emotion perception	P	E	A	N/A
10) Social working memory – mutual and joint attention	P	E	A	N/A
11) Social working memory – retaining social information	P	E	A	N/A
12) Tactile sustained attention	P	E	A	N/A
13) Tactile selective attention	P	E	A	N/A
14) Attentional switching	P	E	A	N/A
15) Sustained attention: interaction – time	P	E	A	N/A
16) Selective attention: interaction – novel condition	P	E	A	N/A
17) Attentional switching: interaction – topic change	P	E	A	N/A
18) Attention manipulation – initiating long-term working memory strategies	P	E	A	N/A
19) Attention manipulation – initiating maintenance cognitive strategies	P	E	A	N/A
20) Attention manipulation – initiating metacognitive strategies	P	E	A	N/A

Table 6. Graph for plotting the response choices.

Domains	Encode						Maintain							Manipulate						
Present (P)																				
Emerge (E)																				
Absent (A)																				
N/A																				
Items	1	2	3	5	6	8	4	7	10	11	12	15	16	9	13	14	17	18	19	20
Behavioral descriptions	Tactile focused attention	Object manipulation (ventral stream function)	Tactile object identification (ventral stream function)	Tactile object location (dorsal stream function)	Spatial navigation (dorsal stream function)	SWM person oriented	Tactile object recognition (ventral stream function)	Tactile spatial recognition (dorsal stream function)	SWM: mutual & joint attention	SWM retaining social info.	Tactile sustained attention	Sustained attention: interaction-time	Selective attention: interaction-novel condition	S WM emotion-perception	Tactile selective attention	Attentional switching	Attentional switching: interaction-topic change	Attention manipulation: long-term working memory strategies	Attention manipulation: maintenance cognitive strategies	Attention manipulation: metacognitive strategies

"The rating of items on the TWMS could be done by direct observation and by video observation."

Table 6 (page 61) shows a graph for plotting the response choices to visually portray the person's working memory profile in relation to each individual item and in accordance with the three domains (Encode, Maintain, and Manipulate).

Some items of the TWMS were chosen in accordance with the behavioral aspects related to the cognitive and the social cognitive components of working memory. Furthermore, items were also chosen based on the dual pathway functions of the somatosensory processing system (see figure 8, page 38). For example, items 2, 3 and 4 may capture underlying ventral stream functions responsible for tactile object identification/recognition, while items 5, 6 and 7 may capture underlying dorsal stream functions responsible for tactile object location/recognition.

The TWMS is not linear or nominal based, and it is not linked to actual score values or cut scores. Although the item arrangement is not linear in nature it is assumed that each processing level (encode, maintain, manipulate) may influence the other.

Nevertheless, in a dynamic assessment approach, once the response choices are plotted and the pre-intervention profile is obtained, relevant interventions could be implemented, and a reassessment could take place (the post intervention profile). A dynamic assessment is a measure of how much an individual tends to change over time due to respond to intervention within the assessment process, in other words, a within-subject-effect.

For instance, if items 18, 19 or 20 are scored as "absent" on the pre-intervention profile, the intervention partner should support the person with deafblindness to perform above the limits of their optimal level of performance, by mediating individualized working memory strategies during the intervention period (see chapter 4.3).

The rating of items on the TWMS could be done by direct observation and by video observation. That is to say, filming and storing the event/activity during the activity. On the basis of video observation, it will be possible for the observer/observers (together with the interaction partner) to analyze the material in a very minute way. Hence, it is an effective way to observe the behavioral cues of tactile working memory. It can be assumed that those subtle behavioral cues could have been missed when direct observation methods are used, since the bodily signals or emotional expressions of people with CDB are often subtle, can unfold at slow pace, pass unnoticed and can be difficult to interpret or read. A challenge many people with CDB face is the low readability of their communicative expressions (Buelund Selling, Creutz & Schjøll Brede et al., 2019).

3

TWMS

Chapter 4

Linking a step wise assessment with intervention

LINKING A STEP WISE ASSESSMENT WITH INTERVENTION

The transactional model of tactile working memory describes working memory as an ongoing process in which the interaction partner optimizes the physical and social environment and supports the person to temporarily store and process information. In this sense, the transactional model highlights the reciprocal, bidirectional influence of the communication environment, the responsiveness of communicative partners, and the person's own developing competence. In other words, the tactile working memory functions of a person with CDB can be better understood by the analysis of the interactive context and not simply by focusing solely on the deafblind person.

Furthermore, the dynamic assessment approach of tactile working memory emphasizes how to implement effective interventions based on the interactive assess-intervene-reassess principles (cognitive modifiability) and accounts for the amount and nature of the mediator investment. The dynamic assessment of tactile working memory suggests that a person who is congenitally deafblind might perform above the limits of their optimal level of performance, when supported by an interaction partner who is able to facilitate social relationships and mediate individualized efficient working memory strategies within the assessment.

In a similar manner, the ecological assessment approach to tactile working memory highlights an asset-based approach that considers the potentials of the person with CDB as well as the different settings and the different people with he/she interacts.

Accordingly, the TWMS assessment should be conducted on the transactional, dynamic and ecological principles. To foster tactile working memory, it is also important that the intervention process is linked to two main principles. Firstly, we need to optimize the physical and social environment of the person with CDB within a bodily-tactile modality. Secondly, the interaction partner needs to mediate effective learning strategies within a bodily-tactile modality. See figure 13, page 67.

4.1 Optimizing the physical and social environment within a bodily-tactile modality

The communication competence of social partners is believed to have a large impact on the quality of interactions with people with CDB (Janssen, et. al., 2003). A hearing and sighted interaction partner does not naturally adapt their communication strategies within a bodily-tactile modality to support the needs of a person with CDB. For instance, a study had shown that the social partners of children with CDB regularly stood outside the child's tactile reach (Vervloed et. al., 2006). Thus, when adapting to the communication needs of the persons with CDB it is necessary to optimize the physical and social environment within a bodily-tactile modality.

The interaction partner fulfills different roles when optimizing the physical and social environment within a bodily-tactile modality. Here are examples of roles.

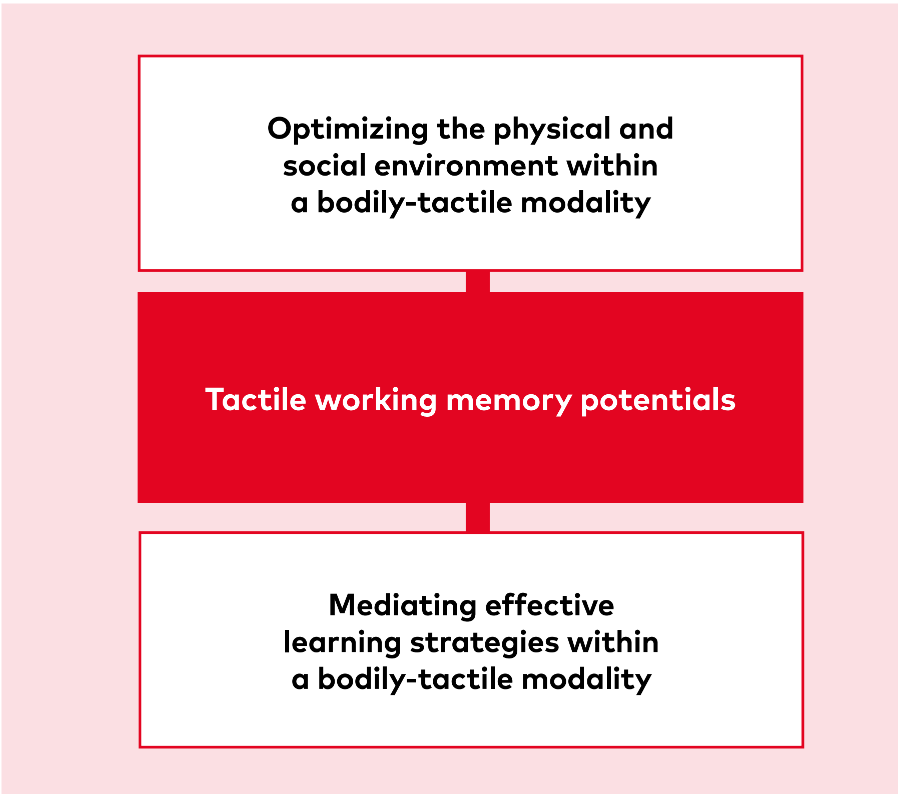


Figure 13. By optimizing the physical and social environment and by mediating effective learning strategies within a bodily-tactile modality during the intervention process, it is highly possible to foster tactile working memory potentials in people with CDB.

4

1) The interaction partner plays an important role in adapting the learning environment, providing possibilities for shared exploration and supporting tactile perceptual strategies, such as providing time, opportunity and supporting active exploratory procedures to systematically explore an object or identify/localize an object/place. Examples of tactile perceptual strategies: tactilely examining a pumpkin together by placing their hands as they explore the relatively smooth parts of the skin and find the stem, leaf and vine; tactilely identifying a location by moving and exploring together the immediate surroundings (wall, kitchen counter and cupboards); helping the person to tactilely estimate the distance between objects (how near or far the kitchen counter is); supporting the person to identify a tactually accessible pathway and navigate towards a specific location (how to navigate towards a kitchen counter).
2) The interaction partner plays an important role in enhancing attentional abilities during interactions.

During a bodily-tactile interaction with a person with CDB, it may at times be difficult to judge whether the person is in need for more time to process earlier experiences or whether the person is not attending to the interaction at all

(Rødbroe & Souriau, 1999). The temporal aspect of processing ongoing information is characterized as processing time. In contrast when the attentional process is prevented from operating in a normal way it is described as attentional disruption. The behavioral aspects of these two attentional processes may seem quite similar and difficult to distinguish. Especially it is difficult to differentiate between the two processes when the attentional disruption is preceded by a period of processing time. However, certain subtle differences may be observed during the interaction.

Example: Bodily-tactile perceptual strategies

Tactilely examining a pumpkin together by placing their hands as they explore the relatively smooth parts of the skin and find the stem, leaf and vine; tactilely identifying a location by moving and exploring together the immediate surroundings of the environment (wall, kitchen counter and cupboards), helping the person to tactilely estimate the distance between objects and how near or far away (kitchen counter to kitchen table) and supporting the person to identify a tactually accessible pathway and navigate towards a specific location (kitchen table).

Processing time is about how the person is able to regulate the intensity and the flow of information during the interaction. This means that the person will resume the correct course after having left it for a while. Accordingly, after taking time to process the information, the person will react and continue the interaction. For instance, the partner could build in slots for the child to respond by pausing to give time to reflect and contribute (Miles & Riggio, 1999).

Example: Processing time

The interaction partner and the person with CDB are playing a hand-clapping game, involving hand movements and a few bodily rhythm patterns. Unexpectedly, the person pulls his hands away, turns his head away and keeps still for a short period. After taking time to process the ongoing information (processing time) he returns to the hand-clapping game. This may be seen as behaviors of time-dependent processing, where the person intentionally regulates the intensity/flow of information and gradually resumes the activity.

An attentional disruption, on the other hand, occurs when there is a discontinuation in the attentional focus or a breach in an action sequence. This means that during the interaction the person's attentional focus is abruptly drawn to another object/activity and is inhibited to return to the initial activity.

If an attentional disruption is observed during the interaction, the partner has two options.

The interaction partner could follow the initiatives of the person with CDB by remaining on his/her altered attentional focus, while sustaining the flow of interaction.

Example: Attentional disruption

The interaction partner and the person with CDB are playing a hand-clapping game. All of a sudden, the person changes her attentional focus to another object in the vicinity (a favorite toy). The interaction partner follows the initiatives of the person, remains in her altered attentional focus and sustains the flow of interaction by focusing on the favorite toy.

Instead of following the initiatives of the person with CDB and remaining on the altered attentional focus, the interaction partner supports the person to return to the initial attentional focus. This may help the person to adapt to both focusing of attention and refocusing of attention (attentional switching).

Example: Attentional switching

The interaction partner and the person with CDB are involved in exploring tactually the keyboard of a piano. All of a sudden, the person changes his attentional focus to another object in the vicinity (a favorite toy). The interaction partner helps the person to return to the initial activity by guiding his attentional focus tactilely back to the keyboard. This may eventually support the person to manage attentional switching and stay focus on the keyboard and the learning experience.

3) The interaction partner enables the deafblind person to become an equal participant by accommodating different bodily-tactile communication strategies or language approaches during the learning process.

Bodily-tactile communication and language approaches

Examples of tactile-based communication or language approaches include: (1) Touch cues/body signs where consistent use of touch or sign is made directly on the child's body to communicate with them (Deuce & Rose, 2019); (2) Haptic signs/gestures is using touch to communicate through agreed touch points and in some instances "drawing" onto the body (Lahtinen, 2008; Raanes & Berge, 2017); (3) Co-active signing involves physically taking the learner's fingers or hands, in a respectful and sensitive manner, to support them to produce a standard manual sign. Through this, the child experiences how to make the sign and learn the hand and finger positions. (Deuce & Rose, 2019); (4) Tactile signing (sometimes also called "hands on" signing or "hand over hand"/"hand under hand" signing) is based on an existing sign language or other manual communication mode and involves the use of touch. This will involve the receiver placing their hands directly over the speaker`s hands to feel the shape, position and movement of the signs (Miles, 2003; Deuce & Rose, 2019); (5) Tactile language in which the basic assumption is that the development of language in the bodily-tactile modality emerges in complex interactions between two or more communication partners. When we add a linguistic value to bodily tactile expressions and recognize tactile languages as natural languages, we are able to communicate linguistically with people with congenital deafblindness (Buelund Selling, Creutz & Schjøll Brede et al., 2019).

(4) The interaction partner plays an essential role in conveying and interpreting messages/utterances but is also to engage in conversations that have mutual interaction and equal participation. In this communication approach, the sensitive and responsive competences of the communication partners are seen as crucial for the child's learning and motivation (Trevarthen, 2001). Partners need to have highly developed skills, sensitivities and insights to participate in the world of children with deafblindness, where touch and proximity are crucial (Janssen et. al., 2004; Nafstad & Rødbroe, 2015). The interaction partner should be able to notice and respond to the bodily-tactile information conveyed by the person. For instance, being aware of how his/her hands/body may convey different information depending on their tenseness of tone, speed of movement, and degree of pressure. This follows on from early communicative experiences, through the ability to establish jointly negotiated meaning of an action/gesture, to then supporting the transition into a cultural tactile sign language (Deuce & Rose, 2019). The ability of the partner to recognize, affirm, support and adapt are vital components of developing a social environment that supports the person´s initiative and engagement. These abilities of the interaction partner are often described as partner competencies.

4.1.1 Partner competencies and social cognitive strategies

A competent interaction partner using social cognitive strategies is keenly aware of the person's bodily-tactile signals, interprets them accurately, and reacts promptly and appropriately so that the person with CDB feels understood. Subsequently the communication or bodily conversations are made accessible for the individual with CDB. Participation in these bodily conversations requires a high level of sensitivity, special insights and considerable skills for the hearing and sighted caregivers (Rødbroe & Janssen, 2007). Examples of important partner strategies are establishing trust, responding to the child's interests, and responding to attempts at communication using the child's expressive forms (Wolthuis, et. al., 2019). Furthermore, studies on social partner support indicate that the provision of interaction support to social partners positively influenced social interactions with people with CDB (Damen, 2015).

The following are some examples of partner competencies that are required to engage in conversations that have equal participation within the bodily-tactile modality. During such harmonious interactions, the individual learns to trust the caregiver's availability as a source of emotional comfort and support (Janssen, et. al., 2003).

Fostering a sense of togetherness (attunement and body-with-body interactions)

A sense of togetherness occurs when the interaction partner is able to attune his/her own acts to the unique emotional expressions or bodily-tactile signals of the deafblind person. Attunement describes how reactive the interaction partner is to the emotional needs and moods of the person with deafblindness and be aware of the range of emotions that they can communicate through the bodily-tactile modality. Thus, by recognizing the emotional state of the person with deafblindness and adapting one´s own response in accordance, the interactional sequences become sharable and more motivating for the person with congenital deafblindness. Furthermore, body with body interactions where two bodies are aligned with each other will make possible the perception of the partners' body in action and the partners´ emotions (Gregersen, 2018).

Example: Fostering a sense of togetherness

When sitting next to or opposite to each other, the interaction partner maintains a close physical contact by letting his or her knee touch the knee of the person with CDB. Thereby, letting the person with deafblindness know that the partner is physical close and accessible. This may also promote attunement and a sense of togetherness. Additionally, it will help the person to follow with ease the new movements or positions of the interaction partner.

Supporting social forms of attention during interaction (mutual attention and joint attention)

During the interaction, the key responsibility of the interaction partner is to detect and then follow the person's social attention. This will be the prerequisite for grasping and interpreting the emotional expressions or bodily-tactile signals that will develop from this focus of attention. Vision isn't the only way to establish mutual attention or joint attention. Through postural changes, tenseness of tone, speed of movement, degree of pressure or other bodily-tactile cues it is possible for the person with CDB to develop mutual attention or joint attention.

Mutual attention is sharing attention to each other or to the shared activity (Trevarthen & Hubley, 1978). In other words, it is about YOU and I (self and the other), are either seeing the same thing, hearing the same thing, smelling the same thing, tasting the same thing or touching the same thing.

Example: Mutual attention

When the person with CDB and the partner touch together the same tree in a bodily-tactile manner.

Joint attention behaviors involve the social coordination of one's own attention with that of another person to better adopt a common point of reference and share information (Mundy, 2018). The primary aim of joint attention is to share experience with other people (Mundy et al., 2009). In other words, it is about "I know you know that we share the same experience' (Janssen & Rødbroe, 2007). Joint attention serves as a self-organizing role in social information processing in early, unstructured social-learning situations (Mundy & Newell, 2007).

Children with deafblindness do not utterly lack the ability to share social engagement and attention with others. Instead, they do so through the bodily-tactile modality. If the access to the partners´ body is such that the person with CDB can make sense of what the partner is doing, they can establish joint attention (Gregersen, 2018).

Joint attention using tactile strategies has also been showed to be an important ability to support, for instance responding to the child's social attention cues, such as head turning (Bruce, 2005). By providing bodily-tactile cues it is possible to direct the person's attention towards the action of others and be able to engage the person in a conscious, goal-related and intentional communication.

Example: Joint attention

When the person with CDB is exploring a tree, the partner shares interest by touching the tree and the hands of the person. Thus, being able to show that they are both interested in the same object. Furthermore, the partner mirrors the actions and movements of the person. Eventually, the person may direct his/her own attention to the actions of the partner by mirroring the same actions and movements in a bodily-tactile manner.

Providing scaffolding during interaction

The type of support given to individuals by others to develop skills that are at a level just above their current developmental level is referred to as scaffolding. Accordingly, scaffolding is when the competent partner supports the person with CDB to move progressively toward stronger understanding and, ultimately, greater independence in the communicative process.

The interaction partner provides the person with CDB with a clear routine or format, which serves as a steady base (scaffolding), on which the person feels stimulated to express his or her opinion, thoughts and memories. In this scaffolding format the interaction partner supports the participation of the person with deafblindness when needed (Janssen & Rødbroe, 2007).

Example: Scaffolding

When a new instrument (hand drum) is being introduced, the interaction partner models the purpose of the instrument by playing the drum in a way that the person with CDB can feel her movements. The person can rest his hands on the hands of the partner, so he can feel her movements and hear the drum as a result. By providing this scaffolding format, the person with CDB may feel stimulated to play the hand drum himself.

Stimulating reciprocity and turn-taking social interactions
When considering reciprocity and turn-taking, there is a need to establish a balanced participation between the interaction partner and the person with CDB within the bodily-tactile modality. Tactile signals for turn-taking may include reaching out with a hand, whereas a signal for turn-giving may be a change of hand position (Janssen, Riksen-Walraven, & van Dijk, 2004). The partner could deliberately change hand positions to invite the person with deafblindness to contribute (Miles & Riggio, 1999).

Example: Reciprocity and turn-taking

The interaction partner sings and tactually signs a song for the person with CDB. At the end of the song, the partner pauses, changes hand positions and waits for the person to show expressions of wanting to hear the song again (movement, gesture or sign).

Establishing multi-party contexts and conversational practices
Multi-party conversational practices occur when the interaction partners involve a person with CDB in a multi-party conversation, giving that person the chance to hear other speakers and switch from one interlocutor to another. This may give a better opportunity for a person with CDB to share experiences or knowledge with others in the bodily-tactile modality.

A multi-party conversational practice may also help the person with CDB to take the role of an "active listener". Listening to communication between others will help balance experience and broaden the world of the person with deafblindness (Miles, 2003). People with deafblindness can only relate themselves to others within dyadic interactions, but within multiparty conversations that same person can relate himself to a group of others (Lundqvist, 2012).

When one of the participants contributes during the multi-party conversation, the other participants may then take a "listening" role. Furthermore, during the multi-party conversation two participants can engage in a dyadic conversation while the third participant may take an "overhearing" role (hearing the conversation of others, without being part of it). Being in the "overhearing" position may put the third participant in a better position to hold the information active in mind and to be tactually involved to follow and contribute to the ongoing conversation. If a person with deafblindness is never invited to overhear conversations of others, he lives with a "skewed experience" of only knowing communication directed towards himself (Miles, 2003).

The development of communication and cognition could be enhanced from an early stage by offering narrative and multiparty conversations to these children with congenital deafblindness (Worm, 2016). There are several approaches to achieve a bodily-tactile multi-party conversational practice where one joins a conversation with at least two others;

(1) a bodily-tactile contact between three or more partners, and the communication-code being mainly movements and gestures
(2) switching of hand-position by having the person´s hands on the hands of two signing persons and engaging in a conversation.

Example: Multiparty context

Two interaction partners and a person with CDB, are sitting physically close to each other. The two interaction partners start a conversation using tactile based sign language, while the person with CDB places his hands on the hands of the two interaction partners, thus taking an "overhearing" role. Consequently, the person with CDB initiates his turn by changing his hand-position, by placing his right hand underneath the hand of one of the interaction partners (talking hand position), while his left hand is gently placed on top of the hand of the other partner (listening hand position).

The above-mentioned examples of partner competencies that are required to engage in conversations that have equal participation within the bodily-tactile modality are necessary not only for developing communication, but also for improving social working memory. The strategies for managing the demands to social cognition and enhancing the quality of social working memory are referred as **social cognitive strategies** (see pages 32 and 71).

4.2 Mediating effective cognitive strategies within the assessment

The role of the interaction partner is not only to follow the deafblind person's lead, but also to guide the person with deafblindness to a given destination by stimulating their ability to learn and adapt when exposed to novelty and challenge. This would translate into learning new things, exploring new environments and using effective learning strategies. The person with deafblindness needs an interaction partner who can clearly mediate individual learning strategies in a smooth manner during tasks/activities and interpersonal interactions. Classifications of learning strategies distinguish between perceptual, cognitive and social cognitive strategies. Three main categories of cognitive strategies will be highlighted here.

1) Cognitive strategies for enhancing the link between working memory and long -term memory (long-term working memory strategies).
2) Cognitive strategies for enhancing working memory and learning (maintenance cognitive strategies)
3) Cognitive strategies for exercising attentional control and organizing learning (metacognitive strategies).

4.2.1 Cognitive strategies for enhancing the link between working memory and long-term memory

One group of cognitive strategies that helps us keep information active in the "here and now" while linking it to information from long-term memory (semantic or autobiographic) are called long-term working memory strategies (LT-WM). The LT-WM is the means of maintaining information from the present and specific episodes from the past and working memory mediates this dynamic coordination (Miyake & Shah, 1999). Hence, a LT-WM strategy is the use of long-term memory to expand the person's working memory capabilities (Ericsson & Delaney, 1999). In other words, you significantly boost knowledge retention as you support and make it easier for the working memory to link new information to already existing schemata stored in our long-term memory.

Two LT-WM strategies for enhancing the link between working memory and long-term memory are given below: elaborative memory strategy and elaborative autobiographical memory strategy.

1) LT-WM strategy: Elaborative memory strategy

An elaborative memory strategy is an active process that involves elaborating on the new incoming information in some way that helps enhance the link to long term semantic memory. Elaborative memory strategies can help us capture information for later retrieval because they form a pattern and make memory more efficient. Some examples of visual or auditory elaborative memory strategies are as follows:

— Organize the information into distinct categories (categorization strategies)
Categorization focuses on putting information in meaningful groups. For instance, natural categorization, such as the classification of birds involves grouping of birds into categories according to physiological similarities (it has a beak and it has wings) or list categorization, such as a shopping list can be segmented into categories (Dairy products, Fruits, Meat, Vegetables)

— Make associations by linking the new information to something that is already familiar (association strategies)
Association involves anchoring the item to be remembered to an existing memory or idea that´s in some way related. There are many ways to anchor information using association strategies such as analogies, metaphors or visualizing. For instance, associating the word you have just been introduced to with another word you already know (word association) or linking the number 1 with a goldfish by visualizing a 1-shaped spear being used to spear a goldfish (visual association).

— Divide the information into chunks (chunking strategies)
Chunking is a strategy to condense a vast amount of information into a single, organized unit. It is the organization of material into shorter meaningful groups to make them more manageable and making the information easier to process. Chunking information can be accomplished by organizing visual or verbal information according to specific categories. For example, (1) acronym chunking, that is taking the first letter of each item of the list (Camera, Rake, Anchovies, Dishes, Lipstick and Envelopes) and making a word (CRADLE), (2) sequential chunking, that is using a counting sequence to recall long sentences/information in smaller segments (one, two, three ...) (3) split chunking, that is grouping a long number/information into groups of three chunks or four chunks (chunking a phone number (91601284), into groups of three chunks (916 01 284) or four chunks (91 60 12 84). There is evidence suggesting that chunking appears to have a major impact in recall memory (Gilbert, et al., 2012).

— Provide memory cues (retrieval cues)
A memory trace may be retrieved more often by reminders or retrieval cues. This can be a sentence completion cue, for example, "The American president at that time was Barack ... That's right, Obama."

It could also be an event cue, for example, if you want to remember what you got for your birthday last year, picture whom you were with, what you were wearing, where you were and then reconstruct the events of that day.

— Mentally hook the information you want to remember to specific locations (method of loci)
The method of loci strategy consists of remembering things by visually placing what you want to remember in places that are familiar to you. To utilize the method of loci, you first visualize a familiar place in a specific order (a house with ten rooms), and then you visually place the things you want to remember in these places (items from a to-do list placed in different rooms). To retrieve the information, you imagine yourself walking through the familiar place (the

house with ten rooms), and then picking up or passing by each item (from the to-do list) that you placed there (in the different rooms). Simply put, you mentally visualize the items you want to remember in particular places.

There are two basic mental processes involved in the method of loci; 1) applying a spatial learning strategy/mental maps 2) mentally visualizing a journey to represent the information you want to remember/ memory journey (Maguire, Valentine, Wilding, & Kapur, 2002).

The essence of this technique is that you have these familiar mental landscapes in your brain, and you dot this landscape with the items that you want to memorize. Although, the method of loci is associated with mental pictures using the visual modality (visual mental imagery), relatively little is known of creating a mental image through the tactile modality (tactile mental imagery).

Tactile mental imagery is when we create coherent mental images by active touch and motion that can facilitate certain aspects of tactile perception. Tactile mental imagery may be mediated visual by mental imagery and consequently people will vary in the vividness of their tactile mental imagery. However, there are some studies that suggest specific brain activation when creating a mental image through the bodily-tactile modality. For instance, a neuroimaging study has reported the involvement of tactile imagery during tactile tasks in an individual with acquired deafblindness (Obretenova, et. al., 2010).

There are several aspects that are necessary to consider when guiding or scaffolding an elaborative memory strategy with a person with CDB. However, learning can be strengthened by using strategies that enhance the link between working memory and long-term memory.

a) Providing the person with CDB with a chunking strategy (sequential chunking/counting sequence). The following is an example of how the scaffolding of a counting sequence can be observed in practice.

Example: Chunking strategy

Two interaction partners are involved in a bodily-tactile activity with a person with CDB. The activity is about pushing and shaking a wet tree, while the rainwater falls on them. The rainwater falls on the person´s head and t-shirt making him wet and excited. Sequential chunking is implemented and a counting sequence is introduced to the next sequence of the activity; pushing the tree trunk. One, two, three ...PUSH! The counting sequence helps him to keep track with the "here and now" information and to relate to what comes later. After several repetitions of the counting sequence and pushing the tree trunk, the person with CDB takes the initiative to start the counting sequence himself.

b) Engaging the person with CDB to make associations between what she/ he already knows and the new information through the bodily-tactile modality (association strategies/ categorization strategies).

Example: Association/categorization strategies

For instance; John, a person with CDB, has a basic understanding of a tree within the bodily tactile modality. Nonetheless, how does John understand a bush or roots? A bush has aspects similar to a tree (John and his interaction partner have to tactually explore the leaves and branches of the bush) but is also similar to a wall (John and his interaction partner have to trail along the edge to find the opening), thus the bush is a "tree-wall".

The same scenario is true for roots, they are the things that trees stand on and connect the tree to the ground, thus roots become "trees feet" and a windblown tree with exposed roots becomes a "fallen tree with feet" (Gibson & Nicholas, 2017).

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c) Providing the person with CDB with a tactile-spatial learning environment to support retrieval of objects and locations in a bodily-tactile manner. (tactile imagery/method of loci)
b) The following is an example of how the scaffolding of an association/ categorization strategy can be observed in practice. The interaction partner guides the person with CDB to make new associations or categorizations about a concept. However, what is important is that the concept is pitched at a level appropriate to deafblind person's understanding of the world within the bodily-tactile modality.
c) The following is an example of how the scaffolding of a tactile mental imagery and tactile spatial learning (method of loci) can be observed in practice. The interaction partner provides a tactile-spatial learning environment for the deafblind person. This may help the deafblind person to create a coherent mental image of an exploration scene and support the retrieval of objects and locations in the environment through the bodily-tactile modality

Example: Bodily-tactile spatial learning strategies

For instance, Peter, a person with CDB, and his interaction partner are in a small room where different type of chairs are placed around in the room. Initially the interaction partner supports Peter to explore this environment and then follows Peter's exploring initiatives.

Peter directs his focus of attention towards the chairs in the room. He uses his fingers, distinct movements and different exploratory procedures to systematic explore the size, shape and texture of the chairs. He explores the chairs in a bodily-tactile manner to identify the similarities and differences among the different chairs. He touches and identifies common features among the group of chairs and seems to be able to classify and recognize them. He moves around locating the chairs. He navigates from one chair to another and is able to determine the relation between the different chairs. He stays focused on this activity for a prolonged time period and he pays attention on the relevant details while filtering out other distractions during the exploration.

He uses a bodily-tactile spatial learning strategy to recognize the spatial relations of objects, to construct sequences and to remember details. He is able to create a coherent mental image of the exploration scene (tactile mental imagery) and seems to retrieve the chairs and their location (tactile spatial learning) in the environment by using active touch and motion. Subsequently, the mental representation of the chairs and their location is matched with object and place representations in his long-term semantic memory and is "readily available" in his working memory during the exploration activity.

2) LT-WM strategy: Elaborative autobiographical memory strategy

An elaborative autobiographical memory strategy is an active process that helps enhance the link to long term "autobiographical" memory. An example of an elaborative autobiographical memory strategy is given below.

— **Create a story to link together information you want to remember (narrative memory strategy)**

Although, autobiographical memory like many other cognitive functions, has been traditionally viewed as an individual matter and a product of the mind or brain, research in the past two decades has revealed the central role of social relationships in cognition and remembering. One such view, which emphasizes the role of social interaction in remembering, is the cognitive – narrative perspective.

The cognitive – narrative perspective suggests an interaction between information processing and a personal narrative process. In other words, event characteristics that are especially important and distinguishable which occur in an individual's life and conversed about with others, would be better stored and recalled than events that are less salient. These life narratives or life stories form the basis of the individual´s remembered self (Greenberg & Rubin, 2003).

According to the cognitive – narrative perspective, three distinct but overlapping processes are involved in the formulation of autobiographical memories, by which autobiographical memories are combined into a coherent life story and related to the current self. These three processes are the

1. construction,
2. co-construction and
3. re-construction of autobiographical memories.

These three processes are distinct but overlapping.

1. A personal narrative format plays a significant role in the construction process of autobiographical memories. This narrative process aids in the retention of a whole episode, and not just fragments of scenes. In other words, narratives are not a biography of the facts and events of a person's life story, but rather the way a person integrates those facts and events internally picks them apart and weaves them back together to make meaning. This narrative becomes a form of identity, in which the things someone chooses to include in the story, and the way he tells it, can both reflect and shape who he is. A life story doesn't just say what happened, it says why it was important, what it means for who the person is, and for what happens next. Thus, a personal narrative format supports the organization of memory as a coherent whole by giving the person a framework that helps him/her to learn how to remember. Narrative is compelling because it provides an account not only of what happens to people, the "landscape of action" but what those involved in the action know, think, or feel-the "landscape of consciousness" (Bruner, 1986).

   Personal narratives, the stories we have about our lives, are created by linking certain events together in particular sequences across a time period and finding a way of making sense of them (White, 1997). A personal narrative format establishes a major form of organization in autobiographical memory by providing the following structures (a) events that recur throughout the story/ script (thematic coherence); (b) placing events into the correct time order (temporal); (c) linking events in a sequence (causal) (Habermas & Bluck, 2000).
2. Memory dialogues or memory conversations about the past play an important role in the co-construction process of autobiographical memory and often require some degree of negotiation. Research suggests that memory

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dialogues with a long-term partner may scaffold successful autobiographical memory (Barniera, et al., 2014). Likewise, for young children, telling memory stories teaches them how to remember. Telling memory stories are social co-constructions rather than independent performances. When children gradually learn to converse about the events from their personal past, they need to get support for their story memory from their parents. A child's learning to engage in narrative conversations about the past with others marks a crucial step in the emergence of an autobiographical memory (Nelson & Fivush, 2004). Children gradually learn the forms of how to talk about memories with others, and thereby also learn how to formulate their own memories as narratives (Fivush & Reese, 1992).

3. The sharing of memory narratives is involved in the reconstruction process and has an important social function of maintaining social bonds by providing material for people to converse about. Sharing personal memories with others is a way to facilitate social interaction and involves the activities of reminiscing and joint reminiscing.

Reminiscing is an activity to talk about personal past experiences. It involves an elaborative style and involves more than recalling details of what occurred and recounting information for factual purposes. On the other hand, the activity of joint reminiscing involves communicating or conversing about shared past experiences with others. Joint reminiscing can be seen as involving a particular form of joint attention, that is, joint attention to the past (Hoerl & McCormack, 2005).

The basic idea of joint reminiscing is that the person comes to value memories of past events because they come to be seen as part of a history that is shared with others. When we share memories of the past we strengthen shared connections, offer sympathy and elicit support.

Research has shown that an elaborative parental reminiscing style that involves the activities of joint reminiscing fosters the development of autobiographical memory skills in children (Fivush, Haden, & Reese, 2006). This elaborative parental reminiscing style consists of encouraging the child to tell stories about what is happening in the world around them. When parents reminisce with their children about past events, they implicitly teach them narrative skills, such as what kind of events are important to remember and how to structure talking about them in a way that others can understand. The ways in which parents' structure conversations about past events with their preschool children has been shown to have a profound effect on the ways in which children come to remember their past and share it with others (Fivush & Vasudeva, 2002).

The way we remember things is that we make narratives out of them. Every time we recall a memory, it undergoes reconstruction, meaning we are able to add new information or a different interpretation to our remembrance. Scaffolding autobiographical memories with appropriate, open-ended and informative cues can promote better recollection of past events. Research experiments into autobiographical memory on what makes a good cue for remembering events have demonstrated that "what" (the event was) was the best retrieval cue followed by "who" (was involved) and "where" (it occurred). "When" (it occurred) was the least effective cue (Gardner et. al., 2012; Wheeler & Gabbert 2017).

There are several aspects that are necessary to consider when guiding or scaffolding an elaborative autobiographical memory strategy in a transactional perspective.

a) Engaging the person with CDB in an activity that includes differing degrees of emotional involvement and that provides a context for shared experiences.
b) Helping formulate personal memories of the event/activity as narratives structures, which aids in providing thematic coherence (events that recur throughout the story: script), temporal aspects (placing events into the correct time order) and causality (linking events in a sequence; describing how one event led to another) (construction process).
c) Engaging in narrative conversations during the event and in memory dialogues immediately after the event/activity (co-construction process)
d) Encouraging the person with CDB to talk or tell stories about a past event (reminiscing)
e) Encouraging the person with CDB to share stories that provide material for conversation about a shared past event (joint reminiscing)

The following is an example of how the scaffolding of a narrative memory strategy can be observed in practice.

The interaction partner engaged the person with CDB in an activity that included differing degrees of emotional involvement and that also provided a context for shared experiences. This shared experience was optimized to enhance the bodily-tactile modality. Many elements in this activity were explored in a joint manner and conversed in a physical tactile manner.

Example: Narrative memory strategies

For instance, Maria, a person with CDB and her interaction partner were going for a walk in the park.

While they were walking in the park, they came across an old tree-trunk. Maria showed interest and started to tactually explore the tree-trunk in a systematic manner. She used distinct movements and different exploratory procedures to systematic examine the tree- trunk and feel its precise tactile characteristics, such as rubbing her hands on the tree-trunk to feel the texture, pressing her hands on the tree-trunk to feel the hardness. She also explored the tree-trunk using motion (gross physical movements), such as by stretching her hands up along the tree-trunk to feel the length of the tree-trunk and holding around the tree-trunk to feel the circumference of the tree-trunk.

While Maria was exploring the tree-trunk, the interaction partner took initiatives to share this exploration activity in a joint bodily-tactile manner, by placing his hands over Maria´s hands when she was stretching her hands up along the tree-trunk; placing his hands over Maria´s hands when she was holding around the tree-trunk (joint exploratory procedure). After this joint exploration activity, they walked around the park for a while and eventually found a bench to sit.

The interaction partner and Maria were engaged in narrative conversations during the entire event (construction process) and in a memory dialogue after the event (co-construction process).

The "joint exploration of the tree-trunk" itself became mini narratives. The interaction partner guided Maria in formulating her personal memory of the event as narrative structures in a way that it aided a thematic coherence (a generic script which encapsulates the key experiences and actions: "having fun when going for a walk") temporal aspects (placing the different activities they did in the park in a correct time line) and causality (linking the different activities they did in the park in a sequence).

A month later the interaction partner visited Maria at her residential care home. They went outside, found a bench with a table and sat side by side on the bench. The partner started a conversation by talking about the cup of coffee which was on the table in front of them. The partner took the initiative for a conversation by facilitating a frame of reciprocal exchanges and turn-taking within the bodily/tactile modality, through the talking and listening hand position approach. During the conversation, the partner gently placed his hand on top of the hand of Maria (listening hand position). Eventually, when the turn-taking occurred, the partner changed his hand-position by gently resting his hand underneath the

hand of Maria (talking hand position). During this conversation the talking- and listening positions were important to scaffold the frame of who is talking and who is listening.

Consequently, Maria puts both her hands in a talking hand position and signed: "Before". She then flexibly switched into a listening hand position. The interaction partner switched his hand position to a talking hand position and signed: "Before, what?" and immediately switched into a" listening hand position". Maria then signed: "Walk" and displayed a "stretching her hands up" gesture.

At this moment, the interaction partner recognized this gesture as something representing the autobiographical memory of the "joint exploration of the tree-trunk tree" experience at the park a month earlier; the bodily-tactile memory of his hands over Maria´s hands when she was stretching her hands up along the tree-trunk. The interaction partner confirmed this gesture by using the same "stretching her hands up" gesture and signed: "You thinking we were together at the park before?" Maria smiles and uses the "stretching his hands up" gesture once again (reconstruction process; joint reminiscing). Although, Maria took the initiative for joint reminiscing and gave a clear cue for retrieving the "what" event (stretching her hands up gesture), the partner could further enhance her reminiscing by providing her with "who" and "where" cues ("You thinking we were together at the park before?").

This example illustrates how the interaction partner provided a powerful boost to trigger a sense of long-term memory by providing her with an efficient use of a narrative memory strategy. The interaction partner was able to create an exciting shared activity for Maria to formulate as a personal narrative. He was able to encourage Maria to share the personal event by supporting a memory dialogue just after the event and provided the talking-and-listening hand positions during the narrative conversation. Furthermore, he provided an opportunity for joint reminiscing and good retrieval cues for remembering the past event. In this way, the interaction partner supported Maria to maintain her autobiographical memory over time by using a narrative memory strategy.

4.2.2 Cognitive strategies for enhancing working memory and learning

One group of cognitive strategies that helps us keep information active according to the needs of the moment ("here and now") are called "maintenance cognitive strategies".

Two maintenance cognitive strategies that help retain information during learning conditions are given below.

1) Maintenance cognitive strategy: maintenance rehearsal

Because information in working memory is fragile and easily lost, it must be kept activated to be retained. Activation is high as long as you are focusing on information, but activation decays or fades quickly when attention is disrupted or shifts away. To keep information activated in working memory for a prolonged period, we can make a purposeful effort to remember it. One important strategy for keeping information in the working memory is called maintenance rehearsal. Maintenance rehearsal as the term implies, consists of using a cognitive strategy that keeps or maintains information in working memory. Through rehearsal, our attention is focused in a purposeful manner that results in automaticity and better recall.

In a developmental perspective, research suggests that parents and caregivers utilize specific strategies to enhance the development of working memory in pre-school children, such as using a rehearsal strategy or a repetition of an experience (Fivush, Gray, & Fromhoff, 1987). Furthermore, the efficient and spontaneous use of rehearsal strategies has been associated with better language skills in young hearing children and in deaf children (Bebko & Metcalfe-Haggert, 1997).

The simple repetition of a speech message has been shown to be an effective conversational strategy for increasing adults' ability to understand the utterance (Helfer, Freyman, & Merchant, 2018). Likewise, a parallel rehearsal process for sign language occurs in fluent signers (Wilson & Fox, 2007).

Rehearsal strategies could also take different forms in the different sensory modalities. Maintenance rehearsal in the auditory modality involves continuously repeating the to-be-remembered verbal material that typically includes rote repetition, either out loud or covertly. An example is the repetition of information in the same order in which it was presented to keep it available for later recall (e.g., repeating a list of words, such as "dog, tree, fork; dog, tree, fork" over and over, or repeating a telephone number over and over again until it is dialed).

Maintenance rehearsal in visual modality involves continuously repeating the to-be-remembered visual information in a sequence of distinct locations and implicates spatial rehearsal. Similarly, spatial rehearsal is involved for maintaining bodily-tactile information through active touch and motion. Spatial rehearsal of tactile information plays a central role as a rehearsal mechanism for tactile working memory (Katus, Andersen, & Müller, 2014). During bodily-tactile interaction it is possible to recognize a tactile spatial rehearsal strategy in a person with CDB (Tunes, 2018).

Example: Maintenance rehearsal strategies

For example during tactile communication, the interaction partner and the person with CDB may continuously repeat the to-be-remembered bodily-tactile information by rehearsing the same movements, handshape, orientation and locations on each other's body with the same intensity and extension several times.

2) Maintenance cognitive strategy: cognitive weeding

During demanding learning conditions it may help to minimize unnecessary cognitive load (Mayer & Moreno, 2003). One example of a load-reducing strategy is called cognitive weeding. Cognitive weeding is an error handling method on how to provide corrective feedback following errors during learning situations.

There are two types of errors that can occur during a demanding learning situation: self-generated errors and intrusion errors. Self-generated errors may "stick" more readily because erroneous responses are produced spontaneously, and the responses may be more likely to be retained. For example, self-generated errors during demanding learning situations may promote the opportunity to learn an incorrect response or recall an incorrect response.

In contrast, intrusion errors are often caused by interference which occurs when information that is similar in format gets in the way of the information that you are trying to recall. For example, people find it more difficult to remember lists of words that sound similar, such as man, map, and mat. This phenomenon is referred as phonological similarity. Moreover, just as phonological similarity among words causes interference in recall of lists of words formational similarity of signs (hand forms) interferes with the recall of lists of signs (Poizner, Bellugi, & Tweeney, 1981).

A cognitive weeding strategy that is involved in handling self-generated or intrusion errors, is called an "errorless learning" approach. As the name implies, errorless learning refers to teaching procedures that are designed in such a way that the learner does not have to make mistakes as he or she learns new information. The "errorless learning" approach refers to a learning strategy that decreases or eliminates the opportunity for incorrect choice selection, therefore maximizing the possibility of a correct response. This means that learning under conditions where errors are prevented ("errorless learning") compared to those conditions where the participant learns by trial and error ("errorful learning"), may subsequently reduce cognitive overload.

Errorless learning may also be a successful approach for teaching concepts and comments to children with disabilities (Ulm, 2011). It is also an excellent way to avoid discouragement, and to build success and self-confidence. Significant anxiety can result in increased self-generated errors; on the contrary, positive emotional factors are favorable for preventing self-generated errors. Positive emotions, such as focussing on positive consequences from pursuit of the activity/task are found to have a significant favourable impact on working memory performances (Ochsner & Gross, 2005; Norvik, Schanke, & Landro, 2011).

However, when trying to implement an errorless learning approach with persons with CDB there are some challenges that need to be addressed. Since the bodily signals or expressions of persons with CDB are often subtle and difficult to interpret it is a challenge to determine when bodily signals are incorrect and need to be error handled (errorless learning) or when bodily signals need to be negotiated (negotiation of meaning). Negotiation of meaning is a form of interaction in which meaning is created by the use of utterances that are perceived, interpreted and elaborated by the interaction partner. (Souriau, Rødbroe, & Janssen, 2008, Booklet III). Hence, it is not always easy to capture or understand the person's self-generated or intrusion errors during learning situations. However, when self-generated or intrusion errors are recognized, the interaction partner could consider implementing an errorless learning strategy and provide a corrective feedback during the interaction.

There are several aspects that are necessary to consider when guiding or scaffolding maintenance cognitive strategies with a person with CDB.

a) Providing the person with CDB with an opportunity for utilizing an efficient error handling strategy during the learning situation/interaction (cognitive weeding)
b) Providing the person with CDB with an opportunity for utilizing an efficient tactile-spatial rehearsal strategy during the learning situation/interaction (maintenance rehearsal)

The following is an example of how the scaffolding of a cognitive weeding strategy and maintenance rehearsal strategy can be observed in practice.

Example: Cognitive weeding strategies

For instance, Elise, a person with CDB and her interaction partner were going for a picnic at the beach. They were driven to the beach in a car.

Elise and her interaction partner were sitting shoulder-to-shoulder at the backseat of the car. Elise seemed pleased to be going for a picnic at the beach and she expressed her emotions in a bodily-tactile way. The partner imitated Elise´s bodily expressions and gradually introduced the bodily-tactile sign/gesture for "happy" (by placing both her hands on to Elise´s chest and moving them in an upwards movement).

They arrived at the beach, went for a walk, explored things and eventually found a place to sit. They sat on a picnic blanket facing each other. The partner took the initiative for a conversation with Elise by facilitating a frame of reciprocal exchanges and turn-taking within the bodily/tactile modality, through the talking and listening hand approach. The partner signed; "It´s nice here". Elise flexibly switched to the talking hand position and signed; "bathing" (by placing her hands on to her chest and moving them in a downwards movement).

At this moment, the interaction partner interpreted this sign not as "sea-bathing", but as an intrusion error for the sign" happy", in accordance with the overall context. In other words, the interaction partner tried to understand Elise´s present emotions in a more holistic way.

The intrusion error may be caused by interference due to the similarity in format between the two signs; "happy" (both hands on the chest with an upwards movement) and "bathing" (both hands on the chest with a downwards movement). The interaction partner subsequently guided Elise by error handling the sign "bathing" and provided her with the sign "happy", without disrupting the flow of the interaction.

This example illustrates how the interaction partner supported Elise's working memory and learning by providing her with a corrective feedback during the interaction **(cognitive weeding strategy; errorless learning approach)**.

Example: Bodily-tactile spatial rehearsal strategies

The interaction partner also provided Elise with an opportunity for utilizing an efficient tactile-spatial rehearsal strategy during the interaction. The partner continuously repeated the movement, handshape, orientation of the sign/gesture "happy" with the same intensity several times; first on Elise's body and then on his own body in a turn-taking manner.

This example illustrates how the interaction partner supported Elise's working memory and learning by providing her with an efficient tactile spatial rehearsal strategy using a co-active signing **(maintenance rehearsal strategy)**.

4.2.3 Cognitive strategies for exercising attentional control and organizing learning

The emphasis about where problems with attention may lie suggests that explicit instruction on regulating attention may provide us with valuable cognitive strategies to support working memory. Such cognitive strategies for exercising attentional control and organizing learning are broadly referred as metacognitive strategies.

Metacognition is defined as the ability to know our own cognitive functions, and to be able to use that knowledge. Metacognition is a state of awareness about one's thinking, and it refers to the processes involved in thinking about one's own thinking (Meichenbaum, et. al., 1985). People who are metacognitive not only track what they are thinking but also monitor how they constructed their thoughts. Processes of metacognition include knowing of factors that influence performance, knowing when and where to use particular strategies for learning, remembering as well as how to monitor one's performance.

Metacognitive strategies refer to methods used to help learners understand the way they learn; in other words, it means strategies designed for learners to 'think' about their 'thinking'. Examples of metacognitive strategies are: games that require active inhibition like freeze dance or musical statues; games that require to start/stop, or slow down/speed up; setting goals; planning-ahead; taking step-by-step approaches to tasks; verbalizing own thoughts (think-aloud); bringing thoughts and actions into consciousness (self-talk); thinking strategies for filtering distractions and performing when additional constraints are imposed upon attention (selective attention); strategies to periodically monitor thoughts and behavior (task monitoring); strategies for remembering to perform a planned action (prospective memory); and strategies to help the learner to understand his/her thinking processes (metacognitive conversation).

Two metacognitive strategies that help exercise attentional control and organize learning are described below: strategies for prospective memory and metacognitive conversations.

1) Metacognitive strategy: strategies for prospective memory

Prospective memory is a form of memory that involves remembering to perform a planned action or recall a planned intention at some future point in time (McDaniel & Einstein 2007). In other words, remembering to remember. Prospective memory is thus described as a form of "memory of the future" and involves several attentional processes such as selective attention and task monitoring. In contrast to retrospective memory which involves the informational content of remembering people or events that have been encountered in the past, prospective memory focuses on when to act (action plan), rather than focusing on the informational content.

Prospective memory contains action plans and intentions (such as, "I must pick up the dry-cleaning today"; "I must remember to buy bread on the way home"). Remembering intentions is in fact much more difficult than remembering events that have happened, and the primary reason is the lack of retrieval cues. When we form an intention, we usually link it either to an event ("after we go to the gym, we'll go to the cinema") or a time ("at nine o´clock I must call John). But these trigger events or times frequently fail to remind us of our intention. This is often because the trigger is not in itself particularly distinctive. The failure to remember an intention (such as, to call John at nine o'clock), may have occurred because little attention was paid to the clock when that time was reached or because there were other competing activities that were triggered by that same time signal. However, by focusing to remember the link between the trigger and the action plan may help us remember to do a planned action/intention in the future.

Example: Prospective memory strategies

For example, when remembering to buy bread on the way home, you should think about what actions you need to take to buy the bread (which route do I need to take to get to the grocery store) and try to form a strong link between the trigger event and your action ("if I take this particular route and when I get to the traffic lights, I'll need to turn left instead of right").

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2) Metacognitive strategy: metacognitive conversation

When learners and teachers talk together about their thinking as they are involved in a problem-solving task or conversation, they construct a metacognitive conversation. It is about how the teacher/interaction partner notices, describes or discusses the learner´s mental processes, while asking questions regarding their thinking process. This shared inquiry is at the heart of a metacognitive conversation. These questions can be shared directly with the learner or can be embedded into a particular task or activity (Tanner, 2012).

Metacognitive conversations may facilitate equal participation and invite the learner into a dialogue about thinking about how they think. When the teacher/interaction partner and the learner are engaged in a conversation while simultaneously talking about their thinking, they construct a metacognitive conversation. These metacognitive conversations play a crucial role in helping the learner to understand their own thinking processes, to be reflective about what they understand, and to strategize about how to resolve their confusions.

There is one important aspect that is necessary to consider when scaffolding metacognitive conversation in a person with CDB.

a) The interaction partner provides the person with deafblindness an opportunity to engage in an overhearing role and a listening role by working through a bodily-tactile multi-party conversation in a turn taking manner.

A multi-party conversation will enable the person with deafblindness to take both an overhearing role (to hear a conversation one is not intended, without being part of it) and a listening role (selectively concentrating on what is being said). Switching from an overhearing role to a listening role during the conversation may put the person in a mentally better position to monitor and develop a deeper understanding of his/her own behavior and thinking processes.

The following is an example of how the scaffolding of metacognitive conversation can be observed and recognized in practice.

This example illustrates that a metacognitive conversation which facilitated equal participation and shared inquiry may have helped the person with CDB to keep track of his own thinking process and actions in an effective way (task monitoring). It also illustrates that metacognitive conversations may enable the person with deafblindness to efficiently move his/her focus of attention back and forth between the different roles (attentional switching) and filter distractions in a flexible way (selective attention). Fostering attentional shifting and selective attention are essential for the development of the executive control mechanisms of working memory.

Equally important is that metacognitive conversations may enable the person with CDB to infer the thoughts/beliefs or emotions/feelings of another person (cognitive/affective perspective taking). Fostering cognitive and affective perspective taking is essential to development of social working memory.

Example: Metacognitive conversation strategies

For instance, John, a person with CDB and his interaction partners Sue and Anne were sitting physically close to each other. John was sitting in the middle. Sue and Anne started a conversation using tactile language, while John placed his right hand on Sue's arm and his left hand on Anne's arm. In this way John was in an "overhearing" role. Being in this "overhearing" role helped John to hear the conversation between Sue and Anne, while there were talking about their travelling plans for the summer vacation. Sue had told Anne that she had plans to go hiking to the mountains and go fishing, while Anne told Sue that she will be visiting her brother-in-law during her summer vacation.

Consequently, John initiated his turn, moved his body slightly forward and changed his hand-position to a "talking position" and signed; "I travelling to South Valley". Both Sue and Anne responded to his utterance and Anne posed a question: "Travelling South Valley, doing what?" John responded by signing: "work, stone" (this meant that he was travelling to South Valley camp to work with stone materials). Sue then joined in the conversation and signed "Wonderful that you tell us about you travelling to South valley".

At this moment John moved his body slightly backwards, removed his right hand from Sue, while he kept his left hand on Anne. Yet, Sue continued to keep her hand on John´s right arm. While the three of them were in close bodily contact, there was a pause in the conversation.

About 30 seconds later, John turned towards Anne, changed his hands to a talking position and signed; "Albert, South Valley? (Albert is someone John knows from before). Sue responded and signed; "Albert, South valley, I don't know. Do you want Albert to be in South Valley?" John again turned his hands in a talking position and signed; "I want Albert to South Valley" (this meant that he wanted Albert to participate and join him at the South Valley camp).

Chapter 5

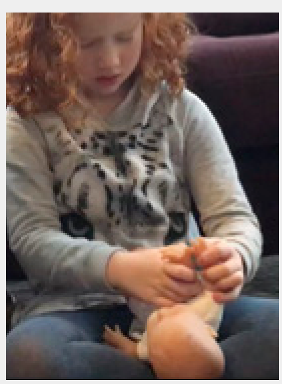
Individual items with photo examples

INDIVIDUAL ITEMS WITH PHOTO EXAMPLES

In this chapter there are a series of photographs to demonstrate and clarify the description of each items. The photographs are extractions taken from video fragments. The persons in the photographs are either deafblind or typical sighted and hearing individuals (models). Because of privacy reasons it wasn't always possible to use images of persons with deafblindness from our daily practice. These photo examples serve as a visual tool to familiarize ourselves with the theoretical construct of the items. This can also support professionals to easily identify and rate the items within the TWMS. However, it is important to note that the behaviors of the items may well look somewhat different from the examples given here.

1 Uses active touch and motion to direct focus of attention towards an object of interest.

The photo illustration below shows how the child uses touch and motion to direct her focus of attention towards an object of interest (newly introduced doll). She reaches out and clutches the doll. She uses her fingertips to understand the larger details of the doll.



2 Uses active touch and motion in systematic exploration of an object of interest.

The photo illustration below shows how the child uses self-generated movements and different exploratory procedures, such as a rubbing/stroking action, pressing into the surface, bending or twisting the object, following the object's surface/edges, to systematic explore an object of interest (the doll). Initially, she judges the surface texture (soft/hard) of the doll by gently stroking and steadily rubbing the doll on her cheek (the first picture). Later on, she wriggles and squeezes the body/head of the doll to determine the shape and she finally traces the fingers of the doll for a finer scale detail exploration (the second and third picture).

3 **Uses active touch and motion to identify similarities or differences among objects.**

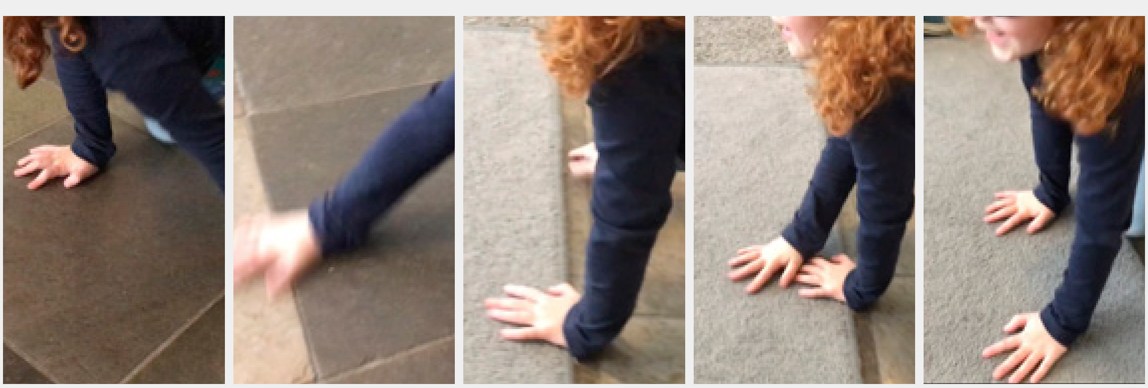
The photo illustration below shows how the person tactilely compares the similarities and the differences between two plastic bottles of different sizes by using active touch and motion. The person uses different exploratory procedures such as framing his hands closely to the bottles body cylinders (the first and the second picture) and following the bottles edges and caps by using his fingertips to match and discriminate the two plastic bottles (the third and the fourth picture).

4 Uses active touch and motion in a purposeful manner to recognize objects in the vicinity

The photo illustration below shows how the child easily recognizes a toy fish among other toys, by touching and exploring the details of the toy fish.

5 Uses active touch and motion to locate an object in the immediate surroundings

The photo illustration below shows how the child uses bodily-tactilely engagement to identify and localize the placement of a floor mat by reaching out and using a swiping hand movement.



6 **Uses active touch and motion to locate a place when navigating within an environment**

The photo illustration below shows how the person uses active touch and motion to navigate from place to place. The photo illustration also shows how she traces the tactile markings of a wooden fence to identify a tactually accessible pathway.

7 **Uses active touch and motion in a purposeful manner to recognize spatial relations among places and objects**

The photo illustration below shows how the person can tactilely recognize the placement of the glass in spatial relation to the plate. The person moves her right hand towards the glass, gently touches it with her fingers before she grasps the glass.

8 **Uses active touch and body movements to intentionally explore and interact with the interaction partner during close bodily contact**

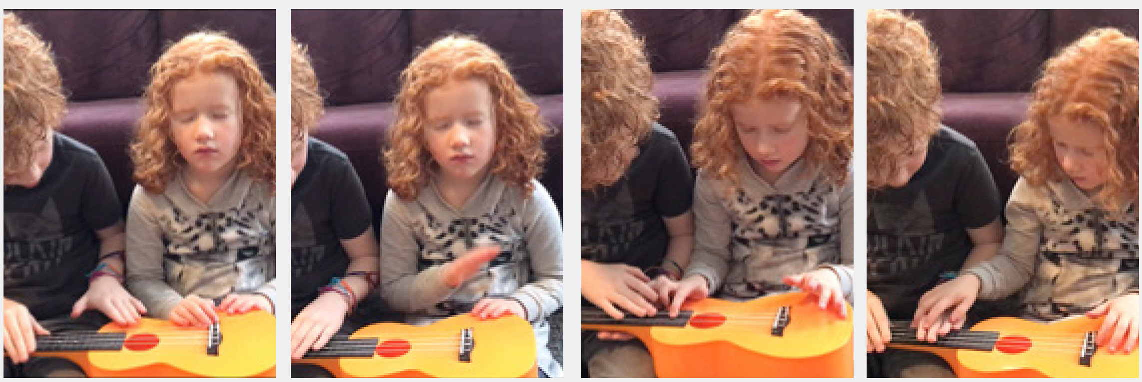
The photo illustration below shows how a child adjusts her hand positions to socially explore the interaction partner in a systematic manner.

9 **Uses active touch and motion to capture the emotionally triggered bodily signals or reactions of the partner**

The photo illustration below shows how a young adult identifies and recognizes a basic emotional expression (happy) of the interaction partner through the partner´s bodily signals and reactions. The young adult confirms the partner's emotional expression in a bodily-tactile manner by tactilely signing happy (by placing both his hands on his chest and moving them in an upwards movement) and shows affection by pressing his forehead against hers.

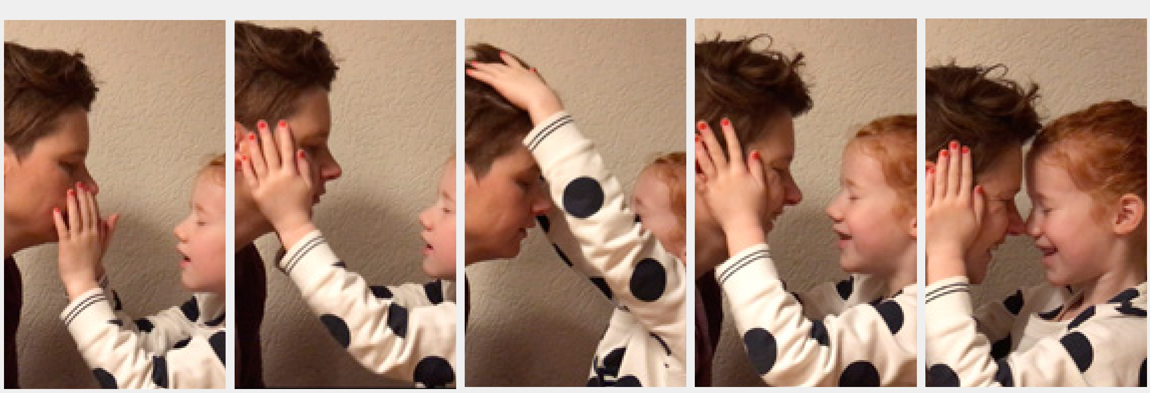
10 **Uses active touch and motion to explore an object together with the interaction partner while displaying behaviors of social attention**

The photo illustration below shows how a young girl shares interest in a ukulele with a peer. Through a close bodily contact she shares her interest in the ukulele by touching together the ukulele (shared attention). Eventually, she directs her own attention to the actions of the boy by mirroring the same actions and movements in a bodily-tactile manner. In the final picture you see her placing her hand on the boy's hand (joint attention).



11 **Uses active touch and motion in a purposeful manner to recognize the partner during the interaction**

The photo illustration below shows how a child adjusts her hand positions to socially explore the interaction partner (touches the partner´s face and hair), gradually recognizes the partner (smiles) and shows affection by drawing the partner towards her (forehead against forehead contact).



12 Uses active touch and motion to stay focused on a specific task or activity for a prolonged time

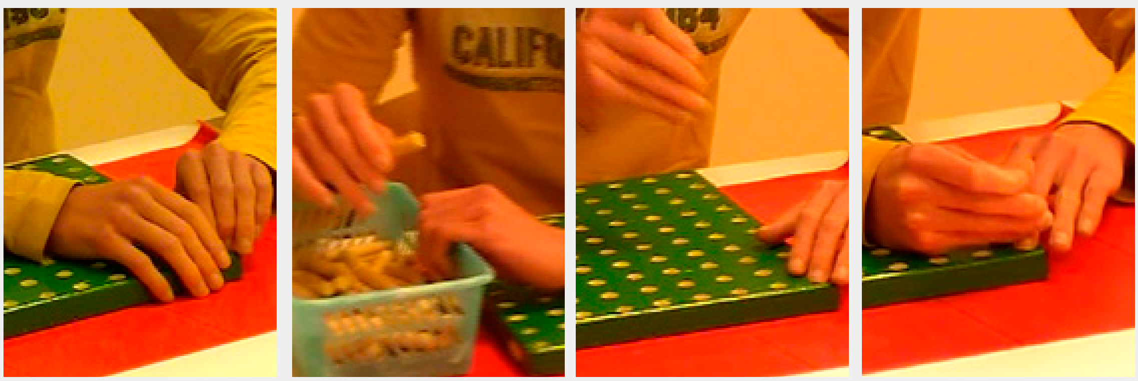
The photo illustration below shows how the person uses active touch and hand movements to stay focused on the peg and rings task. Furthermore, this photo illustration also shows how the interaction partner supports the person to direct her attention to the relevant task and helps her to sustain the flow of attention over time.

13 Uses active touch and motion to pay attention on the relevant details of a task or activity while filtering out distractions or ignoring interruptions

The photo illustration below shows how the person uses active touch and different hand movements to pay close attention to a vibrating electric kitchen mixer. Furthermore, this photo illustration also shows how the interaction partner supports the person to maintain her attentional focus on this activity which involves vibration sensation without becoming easily distracted. She is also able to pay close attention to an important element of this activity (the kitchen mixer).

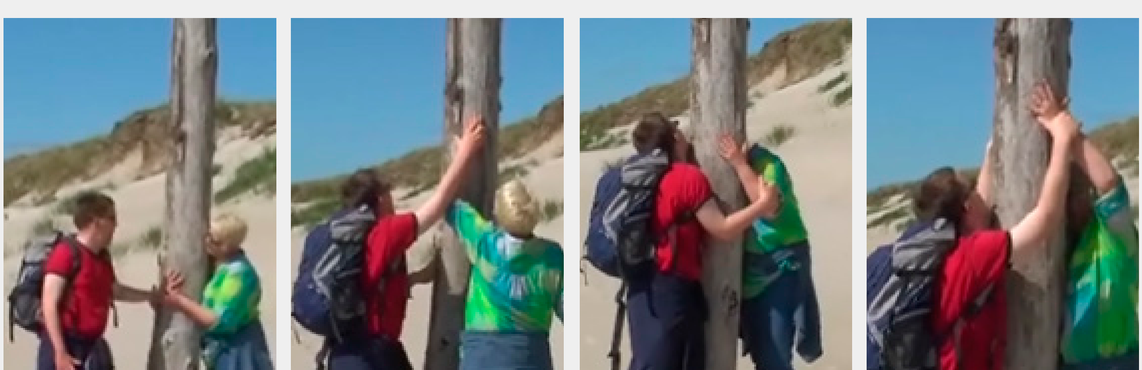
14 **Uses active touch and motion to shift the focus of attention back and forth between different tasks or activity**

The photo illustration below shows how the person switches his bodily-tactile attention from the board to the box of pegs in a flexible manner. Furthermore, this photo illustration also shows how the person focuses and refocuses bodily-tactile attention in accordance with the goals of the activity.



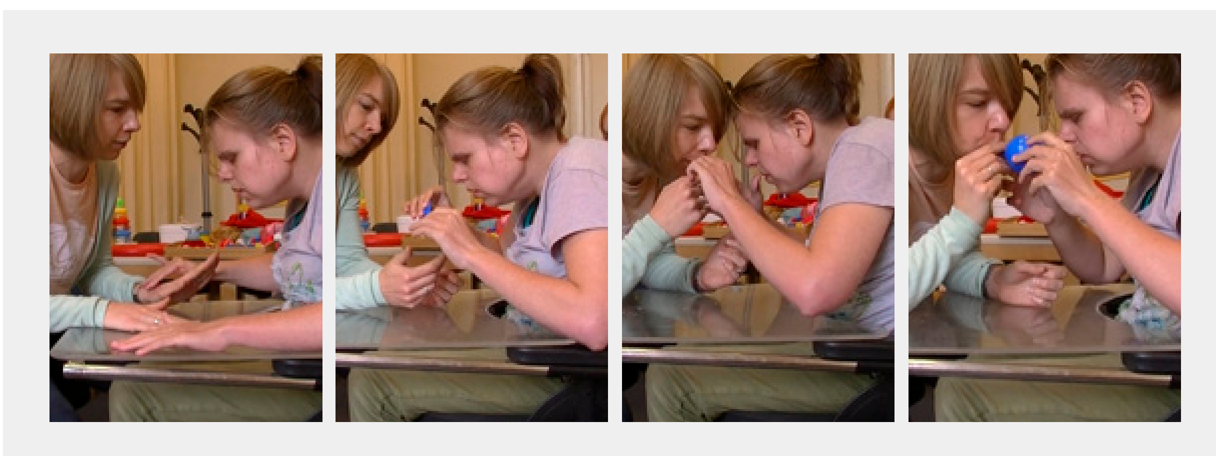
15 **Stays focused on the interaction for a prolonged time**

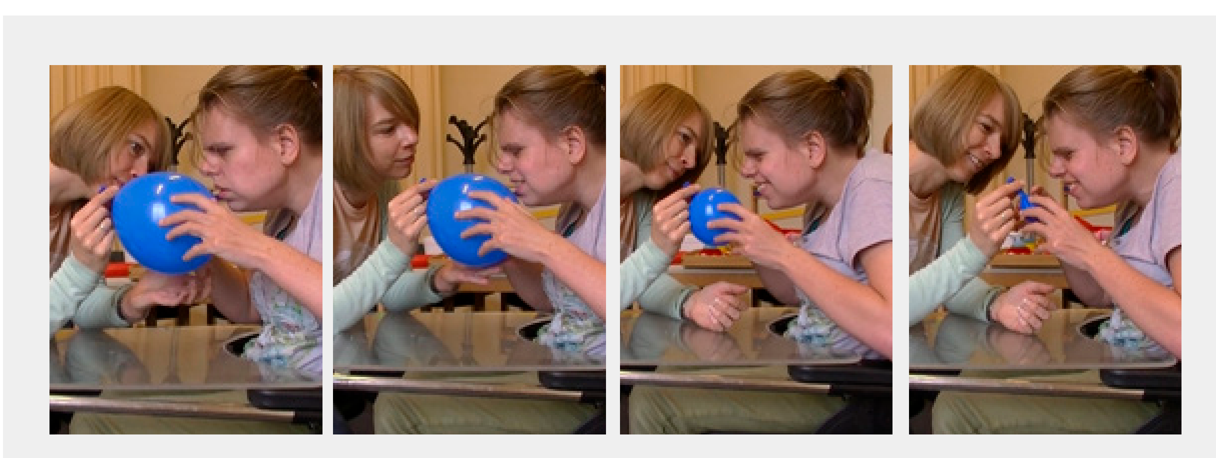
The photo illustration below shows how the person supported by his interaction partner sustains the flow of attention continuously during the "exploring of the tree-trunk" activity. The "exploring of the tree-trunk" activity is performed in a bodily-tactile manner. The person shows initiatives by stretching his hands up along the tree-trunk together with the interaction partner to feel the length of the tree-trunk (joint exploratory procedure). During the joint exploration of the tree-trunk the person also follows the initiatives of the interaction partner and contributes to the ongoing activity and social interaction.



16 Stays focused on the interaction when an unfamiliar/novel feature is introduced

The photo illustration below shows how the person supported by her interaction partner sustains the flow of attention continuously during the “deflated and inflated balloon” activity. After establishing contact with the person, the interaction partner introduces an unfamiliar element (deflated balloon) during the interaction. She actively touches the deflated balloon together with the interaction partner and follows the hand movements of the partner. She shows initiatives by pushing the balloon gently toward the interaction partner. She also follows the initiatives of the interaction partner. When the interaction partner adds a new element by inflating the balloon, she stays focused and smiles clearly. Lastly, when the interaction partner deflates the balloon, the person maintains her attentional focus and smiles as a result of the novel experience.





17 Stays focused on the interaction when switching from one theme/topic to another

The photo illustration below shows how the person supported by her interaction partner moves her focus of attention between themes/features with ease during the ongoing interaction. After being involved in the "deflated and inflated balloon" activity the interaction partner introduces a new bodily-tactile feature during the ongoing interaction, such as blowing gently and deflating the balloon on the person´s forehead. The person adapts in accordance with the changing feature without getting caught up with the older feature. Lastly, when the interaction partner deflates the balloon on the person's forehead, the person maintains her attentional focus to the new feature and reacts with a broad smile.

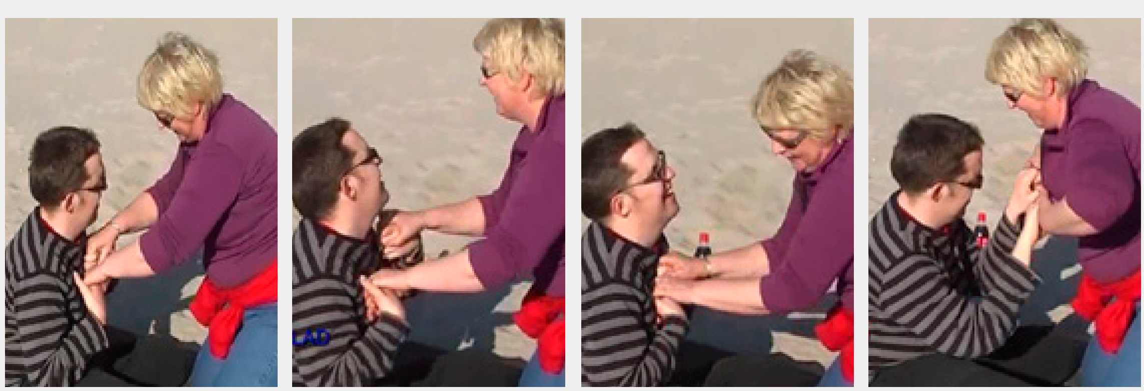
5

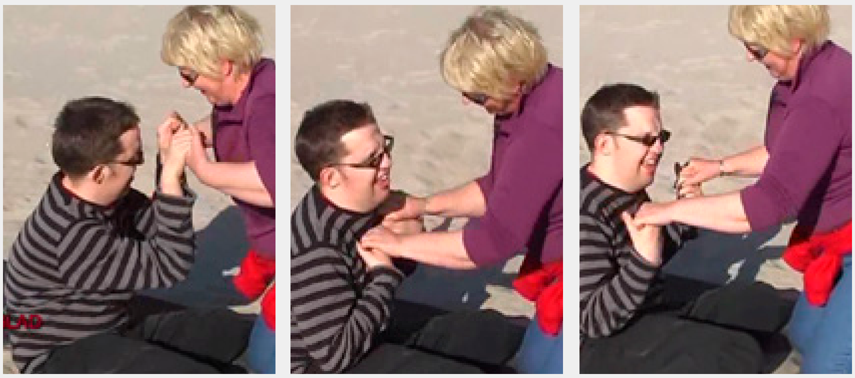
18 Maintains information of specific episodes from the past in the present, especially when partner-guided long-term working memory strategies are provided

The photo illustration below shows how the interaction partner provides the person with a narrative memory strategy to maintain his autobiographical memory over time. The interaction partner was able to create an exciting shared activity for the person to formulate as a personal narrative; "exploring of the tree-trunk" activity (the first two pictures). Later, the interaction partner encouraged the person to share the personal past event by supporting a memory dialogue; joint reminiscing. The talking-and-listening positions were introduced to scaffold the frame of who is talking and who is listening. During the memory dialogue the interaction partner recognized the bodily-tactile gestures as something representing the autobiographical memory of the "joint exploration of the tree-trunk tree" experience, such as stretching his hands up along the tree-trunk and holding around the tree-trunk (the last two pictures).

19 **Maintains information in the present and holds on to the information long enough to use it, especially when partner-guided maintenance cognitive strategies are provided**

The photo illustration below shows how the interaction partner provides the person with the opportunity for utilizing an efficient tactile-spatial rehearsal strategy during the interaction. Furthermore, this photo illustration shows how the interaction partner provides the tactile-spatial rehearsal strategy during the interaction, by repeating together the movement, handshape, orientation of the sign/gesture "happy" with the same intensity and extension several times. Firstly, on the person's body (by placing both his hands on his chest and moving them in an upwards movement) and then on the interaction partner's own body (by placing both her hands on her chest and moving them in an upwards movement) in a turn-taking manner.





20 **Maintains information in the present and actively monitors or makes changes within his/her own learning, when partner-guided metacognitive strategies are provided**

The photo illustration below shows how the interaction partner provides the person the opportunity to take a listening role or an overhearing role during a tactile multi-party conversation. This photo illustration also shows how a metacognitive conversation is carried out as the interaction partners model a dialogue by working through a bodily-tactile multi-party conversation in a turn-taking manner. Initially during the conversation, the person takes a listening role (the first and second picture) and later an overhearing role (the third picture). The tactile multi-party conversation enables the person to switch from an overhearing role to a listening role during the conversation and this puts the person in a mentally better position to monitor and develop a deeper understanding of his own thinking processes. Eventually giving him the opportunity to take an active part in the conversation (the fourth picture).

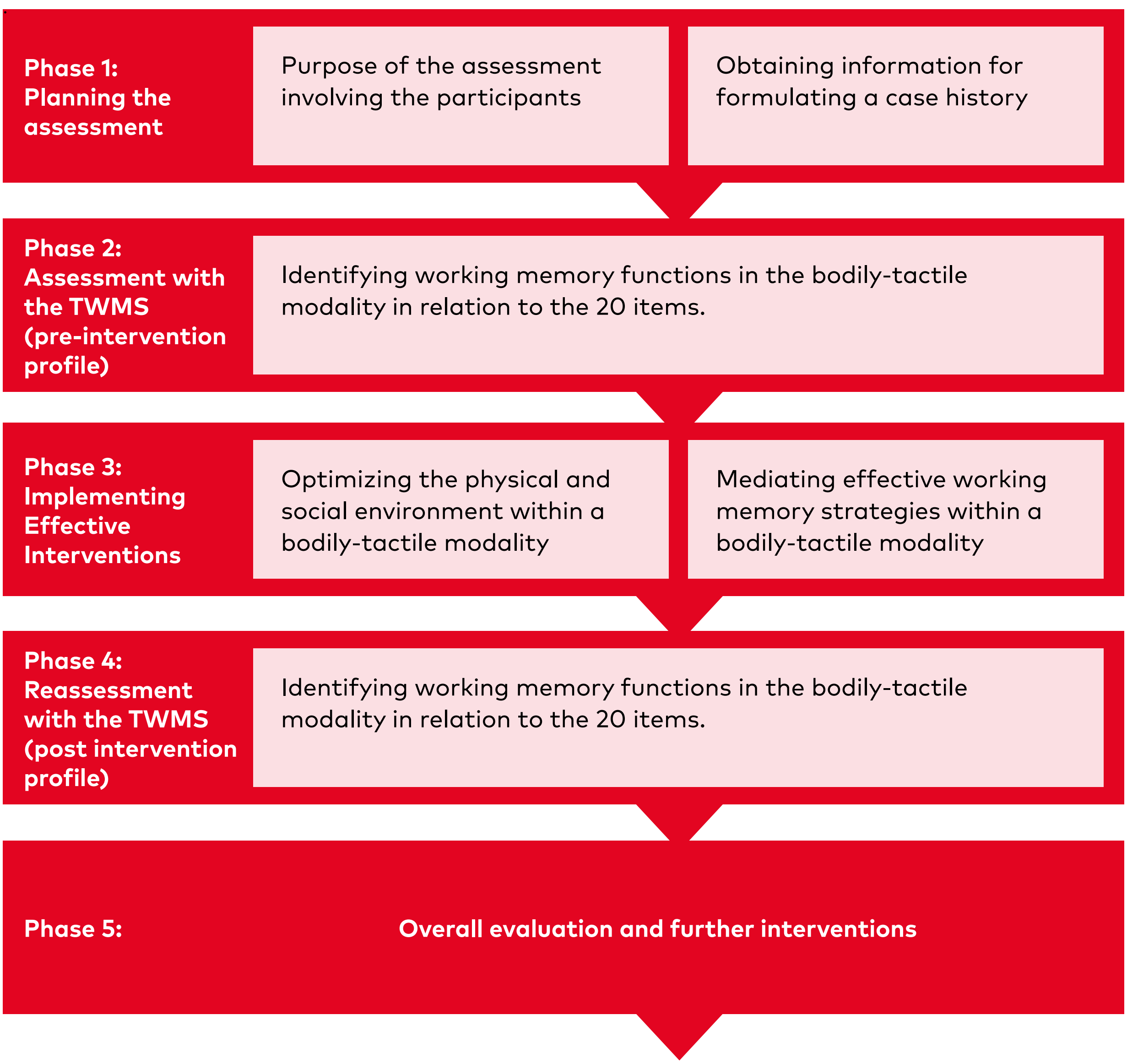
Chapter 6

Analysis of the TWMS assessment exemplified through a case illustration

6.1 A framework for planning and evaluating the assessment

The following model shows a framework when planning and evaluating the TWMS assessment. The model describes five distinct phases. The clinical case presented in this section is illustrated by the five phases of the framework model. See figure 14. The overall evaluation of the TWMS will be based on the comparison between the pre-intervention profile and the post-intervention profile (dynamic assessment approach).

Figure 14. A framework for planning and evaluating the assessment: five phases.



6.1.1 Case illustration

Jack is a 17-year-old young man with CDB. He has CHARGE syndrome with residual vision and hearing. Jack lives with his family and he attends school. However, his combined hearing and visual impairments associated with CDB has severely diminished his access to information from the environment and this may have disrupted his opportunities for communication and language development. In addition, Jack had some self-regulation difficulties due to CHARGE syndrome. Several dimensions of self-regulation (cognitive, emotional/behavioural and physiological) are compromised in individuals with CHARGE syndrome (Hartshorne & Nicholas, 2017). Nonetheless, Jack communicates and expresses himself through vocalizations, a few visual signs and through active touch and motion. Besides, his parents have reported that Jack preferred to communicate with interaction partners who used a bodily-tactile approach combined with visual and tactile signs.

6.2 Phase 1: Planning the assessment

6.2.1 Purpose of the assessment

Jack's parents were concerned that the staff did not fully understand Jack's developmental potentials because they had limited knowledge on how to observe and intervene, especially within the bodily-tactile modality. For instance, the staff at school were finding it hard to understand Jack's bodily expressions/gestures in order to support his communicative development. Jack was referred to the local Community Team for People with Learning Disability for an assessment regarding his functional abilities. He was assessed by observational and psychometrical measures (i.e. Paediatric Evaluation of Disability Inventory) and was categorized as a person with profound intellectual disability. However, the parents did not agree with the given diagnosis and were worried that Jack would not receive the appropriate interventions needed to stimulate or support his cognitive and communicative potentials. The parents requested for a functional assessment that would capture Jack's communicative and cognitive abilities in the bodily-tactile modality.

The primary purpose of this assessment using the TWMS was to obtain a baseline and evaluative profile of Jack's functional abilities in the bodily-tactile modality. Furthermore, the TWMS scale profile could be utilized to identify his adaptive behaviour in the bodily-tactile modality. Adaptive behaviour is defined in terms of conceptual, social, and practical skills involving tasks performed by people in their everyday lives. The TWMS assessment was conducted on the transactional, dynamic and ecological principles, which put the accent on services rather than diagnostics (see figure 11, page 48).

6.2.2 Involving the participants

The parents and the school staff (Jack's teacher and support teachers) were invited to a meeting. The focus of the meeting was to give relevant information about the following: purpose of the assessment, the assessment measure, the assessment principles, duration of the assessment, feedback and follow up. Furthermore, it was emphasized that the school staff and the parents would play an active role during the assessment and intervention period. This meeting was necessary for all the involved participants to obtain a common knowledge, establish a good collaboration and understand their roles during the assessment and intervention period.

After this first meeting, a time period was established regarding the duration of the assessment and intervention period (in this case approximately twelve months). All the involved participants agreed to meet every five weeks during this time period. The initial meetings focussed on how to rate the items of the TWMS and how to obtain a pre-intervention profile. Both parents and school staff were involved in the TWMS assessment.

6.2.3 Obtaining information for formulating a case history

Past medical history and earlier assessment reports were obtained (e.g., audiology/ophthalmology reports, functional vision and hearing evaluations, educational/psychological reports). Interviews with parents and teachers were also conducted. The interviews with parents and staff were designed to collect as much information as possible on Jack's bodily-tactile functions (e.g., how did they recognize his bodily-tactile expressions/gestures, how did Jack use his bodily/tactile functions during tasks/activities, navigation/mobility and social interactions). A case history was formulated based on this information.

6.3 Phase 2: Assessment with the TWMS (pre-intervention profile)

6.3.1 Identifying bodily-tactile working memory functions on the 20 items

The following were described on the TWMS form under general data: Moderate to severe visual loss. Moderate to severe hearing loss. He did not display signs of tactile defensiveness. Gross motor functions were described as good, while fine motor functions and balance/coordination were described as average.

Both direct and video observations were used to capture the behaviours relevant to tactile working memory in Jack's everyday environment. The video observations were recorded during different tasks/activities, with different interaction partners and in different arenas (school and home). This is in accordance with an ecological assessment which implies the importance of collecting information on the everyday functioning of an individual in different settings and with different people.

Table 7. Pre-intervention profile of the TWMS.

Domains	Encode						Maintain							Manipulate						
Present (P)	X	X	X	X		X	X	X			X									
Emerge (E)												X								
Absent (A)					X				X	X			X	X	X	X	X	X	X	X
N/A																				
Items	1	2	3	5	6	8	4	7	10	11	12	15	16	9	13	14	17	18	19	20
Behavioral descriptions	Tactile focused attention	Object manipulation (ventral stream function)	Tactile object identification (ventral stream function)	Tactile object location (dorsal stream function)	Spatial navigation (dorsal stream function)	SWM person oriented	Tactile object recognition (ventral stream function)	Tactile spatial recognition (dorsal stream function)	SWM: mutual & joint attention	SWM retaining social info.	Tactile sustained attention	Sustained attention: interaction-time	Selective attention: interaction-novel condition	S WM emotion-perception	Tactile selective attention	Attentional switching	Attentional switching: interaction-topic change	Attention manipulation: long-term working memory strategies	Attention manipulation: maintenance cognitive strategies	Attention manipulation: metacognitive strategies

There were also sessions with the assessor interacting with Jack. This was necessary for the assessor to get an idea of how Jack was using his bodily-tactile modality during interaction. By interacting with Jack in the bodily-tactile modality the assessor was able to gather important information on how to plan the intervention; for instance, how to recognise and confirm his bodily-tactile expressions, and how to capture his attention in a bodily-tactile manner.

Video observations were used to capture the subtle behavioural cues of tactile working memory which unfolded at a slow pace and might have passed unnoticed. The recordings of the video observations which allowed repetition and multiple viewings of the same activity/interaction were helpful in noticing and describing the behavioural cues relevant to the TWMS items.

The response scores on the TWMS were then plotted on a graph, thus visually portraying Jack´s tactile working memory profile in relation to the 20 items.

This formed the pre-intervention profile. See table 7 page 113.

Briefly, the pre-intervention profile illustrated that Jack's scores were characterised by an item to item variation with some clearly observable behavioural cues on several TWMS items.

In the ENCODE domain, 5 of 6 items were rated with a "Present" score. He was clearly displaying behaviours of tactile focused attention, object manipulation, tactile object identification, tactile object location and person oriented social working memory (items 1, 2, 3, 5, & 8). However, his behaviours related to spatial navigation were rated with an "Absent" score (item 6).

In the MAINTAIN domain, 4 of 7 items were rated with either a "Present" or "Emergent" score. He was clearly displaying behaviours of tactile object recognition, tactile spatial recognition and tactile sustained attention (items 4, 7, & 12) while partially displaying behaviours related to staying focused for long periods during the ongoing interaction (item 15). Besides, behaviours related to social attention, retaining social information and paying close attention to an unfamiliar feature during, were rated with "Absent" scores (items 10, 11 &16).

In the MANIPULATE domain, all 7 items were rated with "Absent" scores. Hence, behaviours related to emotional perception, executive control (tactile selective attention/attentional switching) and initiating cognitive strategies were not observed (items 9, 13, 14, 17, 18, 19 & 20).

Overall the pre-intervention profile showed that Jack was ENCODING bodily-tactile information adequately. This means that he was relying on his somatosensory system to perceive and experience the world. The TWMS profile showed that he was processing information related to ventral stream function (tactile object identification/recognition) and dorsal stream functions (tactile object location/recognition) equally well. However, his navigation spatial skills needed specific attention. The profile also showed that Jack was MAINTAINING the cognitive components of working memory better than the social components of working memory. The TWMS profile also displayed that Jack had difficulties MANIPULATING information related to emotion perception, executive control and in initiating cognitive strategies during problem solving and social interaction.

6.4 Phase 3: Implementing Effective Interventions

The pre-intervention profile was used as a starting point to focus on how to implement effective interventions based on the interactive assess-intervene-reasses principles of dynamic assessment (see figure 11 page 54). The recordings of the video observations were used to identify the essential priority areas of intervention necessary for enhancing Jack's working memory.

Based on the pre-intervention profile there were several areas that needed focus during the intervention period. Some of the items of the scale were rated as "absent" because it was not possible to observe those behaviors that were relevant to the TWMS items. One possible explanation could have been that Jack´s physical/social environment was not adequately optimized within the bodily-tactile modality. According to the transactional model of working memory, working memory should be considered as a dynamic process, characterized by unique individual features predominantly facilitated through social interactions and affected by multiple levels of the surrounding environment (see figure 10, page 45). Hence, to optimize the physical/social environment, parents and staff were supervised to engage with Jack in a bodily-tactile manner. Parents and school staff were supported to implement social cognitive strategies and enhance the quality of Jack's social working memory. Especially, by fostering his social forms of attention (mutual attention/joint attention) and emotion perception during social interactions.

Although the the pre-intervention profile showed that Jack was displaying behaviours related to tactile perceptual learning (object manipulation, tactile object identification, tactile object location), the intervention emphasized on enhancing his tactile perceptual abilities. For example parents and staff were advised to adapt a learning environment that provided possibilities for shared tactile exploration and opportunities to support his tactile perceptual strategies and exploratory procedures (see page 67 and page 25, figure 3). Active exploratory procedures were necessary for Jack to improve his ability to systematically explore, identify and locate objects in his environment.

> "Parents and school staff were supported to implement social cognitive strategies and enhance the quality of Jack's social working memory."

Furthermore, attention was given for providing Jack with a tactile-spatial learning environment that would enhance his spatial navigation. For example, his parents were advised to guide Jack to tactilely identify a location by moving through an environment (from the garden towards the house), exploring together the immediate surroundings of the environment (fence, wall, corners, door) and supporting Jack to identify a tactually accessible pathway (finding a route by following the fence) towards a specific location (inside of the house).

Parents and school staff quickly learned how to interact with Jack in a bodily-tactile manner. They were given a basic understanding on the different cognitive and metacognitive strategies and how to implement them in the bodily-tactile modality. Several short seminars on the topic of "how to teach a deafblind learner effective tactile learning strategies" were held during the intervention period.

Parents and staff were supervised: (a) to support Jack to make associations by linking the new objects they explored together to the objects they had tactilely explored before (association strategies); (b) to create opportunities for Jack to formulate memories of shared activities as narratives within the bodily-tactile modality. For example, the event of exploring his immediate surroundings were formulated as narratives and he was encouraged to share his personal story through a memory dialogue (narrative memory strategy); (c) to provide Jack with a bodily-tactile rehearsal strategy, allocate time for rehearsal during interactions and try to make the repetition as much fun as possible (maintenance rehearsal strategy); (4) to initiate opportunities for tactile multi-party conversational practices which facilitated shared inquiry, perspective-taking through a set of different roles, reversing roles and flexible thinking (metacognitive conversation). Furthermore, involving him in conversations which facilitate equal participation may enable him to improve his social working memory, for instance cognitive/affective perspective-taking or social monitoring.

Regarding his tactile attentional abilities, special focus was given to improving his tactile selective attention and attentional switching skills by implementing other metacognitive strategies. These included step-by-step approaches to tasks/activities, games/activities that required him to start/ stop or slow down/ speed up and thinking strategies for performing in the presence of distractions.

6.5 Phase 4: Reassessment with the TWMS (post intervention profile)

Approximately 12 months after the pre-intervention assessment, Jack was reassessed with the TWMS. The response scores on the TWMS were then plotted on the graph. This formed the post-intervention profile (see table 8, page 117).

TWMS item scores were characterized with clearly observable behavioral cues on almost all of the 20 items on the post-intervention profile. Except for three items that were rated with "Emergent" scores (items 13,14,17), all the other items were rated with a "Present" score. When comparing the pre-intervention profile with the post-intervention profile we could see a significant change, suggesting that the recommended interventions had a positive impact on Jack´s bodily-tactile working memory.

6.6 Phase 5: Overall evaluation and further interventions

The TWMS assessment is based on a transactional approach where the development of tactile working memory is understood as a dynamic process between internal mental processes and physical/social environmental interactions. By optimizing the physical and social environment and by mediating individualized

Table 8. Post-intervention profile of the TWMS (with the pre-intervention graph as a dotted line of reference).

Domains	Encode						Maintain							Manipulate						
Present (P)	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X
Emerge (E)															X	X	X			
Absent (A)																				
N/A																				
Items	1	2	3	5	6	8	4	7	10	11	12	15	16	9	13	14	17	18	19	20
Behavioral descriptions	Tactile focused attention	Object manipulation (ventral stream function)	Tactile object identification (ventral stream function)	Tactile object location (dorsal stream function)	Spatial navigation (dorsal stream function)	SWM person oriented	Tactile object recognition (ventral stream function)	Tactile spatial recognition (dorsal stream function)	SWM: mutual & joint attention	SWM retaining social info.	Tactile sustained attention	Sustained attention: interaction-time	Selective attention: interaction-novel condition	S WM emotion-perception	Tactile selective attention	Attentional switching	Attentional switching: interaction-topic change	Attention manipulation: long-term working memory strategies	Attention manipulation: maintenance cognitive strategies	Attention manipulation: metacognitive strategies

learning strategies (perceptual, cognitive, metacognitive) within a bodily-tactile modality, Jack was able to enhance his tactile working memory functions. A major outcome of this dynamic assessment is that increased experience and effective use of strategies within the bodily-tactile modality could have helped him to keep track and efficiently process cognitive and social cognitive information, during ongoing tasks/activities and interpersonal interactions.

The TWMS assessment gave a clear indication of how Jack maintained his attention within the bodily-tactile modality and thereby providing insights into his emerging working memory capabilities. For example, how he used his touch and movements in a purposeful manner to explore the similarities and differences in objects, how he managed to maintain social working memory while he explored different objects and shared them with his partner in a bodily-tactile manner and how he recognized his partner's emotions through touch and movement. Furthermore, when his school staff mediated different cognitive or metacognitive strategies through the bodily-tactile modality, he was able to sustain his attention for a prolonged time and he took more initiatives to explore objects in the environment. He was now taking the initiative to engage in conversations in the bodily-tactile modality. Moreover, there were indications suggesting that Jack was regulating his emotional expressions in a more appropriate way (e.g. by expressing his feelings in the bodily-tactile modality, using new tactile signs to share his feelings and experiences; able to refocus attention away from strong emotions).

However, Jack still needed his interaction partners to support him in activities that were vulnerable for distractions and attentional shifts during tasks/activities and social interactions/conversations.

The overall evaluation suggested that the TWMS assessment was able to identify Jack's bodily-tactile working memory potentials based on the interactive assess-intervene-reassess principles of dynamic assessment. Furthermore, the assessment also identified how Jack was using different learning strategies in everyday life.

"The overall evaluation suggested that the TWMS assessment was able to identify Jack's bodily-tactile working memory potentials based on the interactive assess-intervene-reassess principles of dynamic assessment."

There was a likelihood that Jack could develop his working memory potentials further, based on the role of experience-dependent learning and neuroplasticity. However, there was a need for further intervention. Jack should be supported to interact more with others in the bodily-tactile modality, reflect on his experiences, talk about what he is doing and why and transfer his good working memory skills to other situations or activities of increased levels of complexity and novelty.

Supervision for the staff and parents was recommended. Both staff and parents need to develop more skills and insights to participate in the world of Jack, where active touch, motion and proximity are crucial. Besides they need to learn more about the different perceptual, cognitive and social cognitive strategies in the bodily-tactile modality and how to mediate these strategies in an effective and smooth manner.

By promoting partner competencies and providing individualized perceptual, cognitive and social cognitive strategies within a bodily-tactile modality Jack would be able to consciously work with bodily-tactile information, adapt learning strategies and internalize the different strategies in order to apply these to other situations/activities of increased level of complexity, novelty, and abstraction. Furthermore, the support provided by the different strategies within the interaction may serve to enhance his tactile linguistic communication and facilitate his tactile language development.

Tactile working memory has an important role for tactile language processing; it serves as a temporary holding area for incoming and outgoing linguistic information, retrieves stored semantic information from long-term memory, inhibits irrelevant information during immediate processing and selectively attends to specific information during bodily-tactile conversations.

TWMS

Chapter 7

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The development of the Tactile Working Memory Scale (TWMS) has been a challenging experience. The decision to develop a practical scale and write a theoretical manual was to build a bridge of awareness on understanding tactile working memory in general, and particularly in people with deafblindness. It all started out with a professional curiosity of whether it was possible to recognize and describe bodily-tactile cognitions in people with deafblindness.

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Working memory, or the ability to keep something in mind for a limited amount of time is a central function in cognition. For persons with congenital deafblindness we need a bodily-tactile perspective on working memory. This manual gives a theoretical overview and presents a scale that can be used by professionals to identify and assess tactile working memory in persons with deafblindness, and design tools and strategies to ensure that these persons can develop and make use of all their potentials, both cognitively and linguistically.

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