# Designing new technology for neuro developmental disorders and the importance of involving users (not only robots)

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## Abstract

Mental disorders including neurodevelopmental difficulties are frequent, creating a substantial disparity between the demand for mental health care and the available resources. The potential of therapeutic technologies to address this treatment gap is immense, offering scalable solutions to enhance access. Yet, the intricate nature of mental disorders, woven with diverse risk factors, poses challenges to a comprehensive understanding of their mechanisms and assessment of this potential.

Current assessments of mental disorders heavily rely on the expertise of trained clinicians, making it imperative to explore innovative avenues such as "digital phenotyping" to capture nuanced behaviors. However, integrating technology into healthcare encounters obstacles exacerbated by the divergent cultures of medical professionals and engineers. While technical feasibility is a priority for engineers, it often needs to match the acceptability standards set by healthcare professionals.

Navigating the complexity of the healthcare ecosystem compounds the challenge of identifying precise needs. Furthermore, the time-intensive nature of clinical research methods hinders the swift evaluation of efficacy. To surmount these hurdles, we advocate for the incorporation of user-centered design methodologies and participatory research in the development of therapeutic technologies.

This chapter delves into the multifaceted challenges of designing technologies, such as robots, for therapeutic programs focused on individuals with neurodevelopmental disorders. By proposing solutions that prioritize participatory co-design environments, we aim to

empower individuals from diverse backgrounds to collaboratively support those undergoing therapy with technology, ensuring its efficacy and benefits.

# 1. Unmet needs of access to care

## 1.1.Treatment gaps in mental care

Mental disorders are very frequent and impairing (Vigo et al., 2016). World Health Organisation reports that, independently of all mental disorders, depression is the first cause of disability in the world (WHO, 2017). However, access to care is very limited. The bulletin of the World Health Organization reports that between 32.2% of schizophrenia, 56% of depression, and 78.1% of alcohol abuse and dependence patients did not have access to care (Kohn et al. 2004). Even when the difficulties are emerging and easier to resolve in child and adolescent psychiatry, the situation is poor. In France, access to care is around 50% in child and adolescent psychiatry (*Cour des comptes*, 2023) and can be much lower in other countries. Neurodevelopment disorders are frequent in 10-15% of the population. They have the highest cost per patient (Christensen et al., 2020). Autism Spectrum Disorder prevalence is 0.70-3 %. Developmental coordination disorder prevalence is 0.76-17%. Learning disorders prevalence is 3-10%. Attention Deficit Hyperactivity Disorder prevalence is 5-11%. Language disorders and communication prevalence is 1-3.42%. Intellectual deficiency prevalence is 0.63% (Frances et al., 2022). Many emerging technologies aim to tackle the mental health treatment gap, particularly mobile applications (Torous et al., 2021).

## 1.2.Potential of new technologies

New technologies were already used to facilitate communication in psychiatry (telepsychiatry). In this chapter, we will discuss emerging technologies using either special sensors and machine learning techniques (automatic assessment and rehabilitation) or technologies giving (semi-) autonomous care (applications -apps-, interaction scenarios, robots).

New technologies could help to tackle access to care thanks to several properties : (1) better measure and monitoring of the behavior of the user (“digital phenotyping”) (Oudin et al., 2023) with proper measures, (2) the ability to integrate these measures to regroup the users in categories and predict the evolution (prognostic) (precision psychiatry), (3) the possibility to scale up and adapt the measures and therapeutic strategies more easily.

In more detail:
(1) new technologies are prone to precisely record the interaction with the user (use of an app, interaction with a robot, a remote control, an interface). For instance, digital phenotyping is a field of research that aims to characterize it. It could be helpful to support either screening of the disorder or to guide the reeducation based on appropriate features. We can mention motor computing to measure movements (posture, movement characteristics, head pose, gaze), e.g. in autism (Gargot et al., 2022; de Belen et al., 2020), measures of emotions affective computing (sadness, fear, frustration, stress) with cameras or wearables (Kaliouby et al., 2006), analyzing language with natural language processing (Le Glaz, et., 2021).

(2) from these features, it is possible to use models to make categories or predict evolution that could be useful for a final aim to adapt clinician or technological system accordingly, for instance, from writing features, a model based on electronic tablet features (Asselborn et al., 2018) could extract different clusters/subtypes of handwriting (Gargot et al., 2020) that could have different prognosis for rehabilitation needs (precision psychiatry). These new technologies allow us to go beyond the classical categorical and symptoms-based Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria (American Psychiatric Association, 2013). For instance, They could help better define psychiatric disorders with network symptoms analysis (Borsboom, 2017).

(3) like any software, they can be quite easily scalable. Software is easy to copy and then scale up without any loss from the sharer. The field of open data aims to share databases and models that enable the transfer of knowledge and tools more easily between users and researchers with a minimal cost, thanks to the internet to facilitate reusability, transparency, and development. Meditation apps like “Headspace” were downloaded by 70 million users, and “Petit Bambou” was used by 8 million.

Beyond communication, new technologies offer tremendous perspectives in care like recording thoughts and emotions (ecological momentary assessment -Shiffman et al., 2008-), training sensory or motor difficulties that are early impaired in children with neurodevelopmental disorders and offering possibilities of compensation to alleviate memory, planning and time management, emotion regulation strategies, reading difficulties.

Broadly speaking, emerging technologies can potentially enhance the characterization of behaviors associated with mental disorders, a concept known as "digital phenotyping" (Insel, 2017). Currently, such behaviors are primarily evaluated by trained clinicians. The integration of new technologies can contribute to a more comprehensive understanding of mechanisms underlying mental disorders, particularly in the context of normal and pathological human development, shedding light on the dynamics of behavioral changes.

Unfortunately, very often, technologies are not developed, either with end-users, or experts in the mental health field like psychiatrists or psychologists (that can limit their customization to the needs of the field). Also, they are not based on an evidence framework (for instance, learning principles and cognitive and behavioral therapy), and their efficacy (is it working at the end on the field ?) needs to be assessed properly.

Beyond their efficacy, several concerns can be raised. Are they acceptable (Bourla et al, 2018)? Can some technologies be palliative of a poor organization of society or healthcare? Technology development informs what is possible, but some technologies should not be used. Are they usable for the user? Are they respecting their practice? In the end, are they cost-efficient? A good design involving users early in the process can help to understand the challenges better and answer the relevant needs of the end-users.

## 1.3 Usage scenarios should be defined from the field

### Acceptability, expectancy, and organizational challenges

Technologies should enhance the psychiatrist/therapist-patient relationship and access to care rather than replace it. We propose a model to describe the development process of new technologies from the treatment gap until healthcare system integration that shows these several challenges of designing and evaluating new technologies in psychiatry and healthcare in general (Figure 1). This process takes several years to implement.

Defining the usage scenario can be difficult, and some practices can induce some reluctance in professionals (are they replacing the professional that feels threatened?, what is the system's performance, and how to deal with the accountability of the professional?) As a result, it is important to define well the user scenario (when it should or should not be used) and the usability needs to be assessed early before any dissemination (Blankenhagel, 2019; Inal et al., 2020).

Venkatesh et al. (Venkatesh et al., 2003) described the Unified Theory of Acceptance and Use of Technology model (UTAUT). It is a technology acceptance model defined in 4 constructs: (1) performance expectancy, (2) effort expectancy, (3) social influence, and (4) enabling conditions. In a survey, Alaiad and Zhou assessed the determinants of home healthcare robot adoption. The most important determinants were performance expectancy, social influence, trust, privacy concerns, ethical concerns, and facilitating conditions with social influence (the extent to which a stakeholder perceives that significant others believe he or she should use the device) (Alaiad and Zhou, 2014). Stahl et Coeckelbergh (Stahl & Coeckelbergh, 2016) argue that ethics should be embedded in practical settings from the design of new systems and innovative practices.

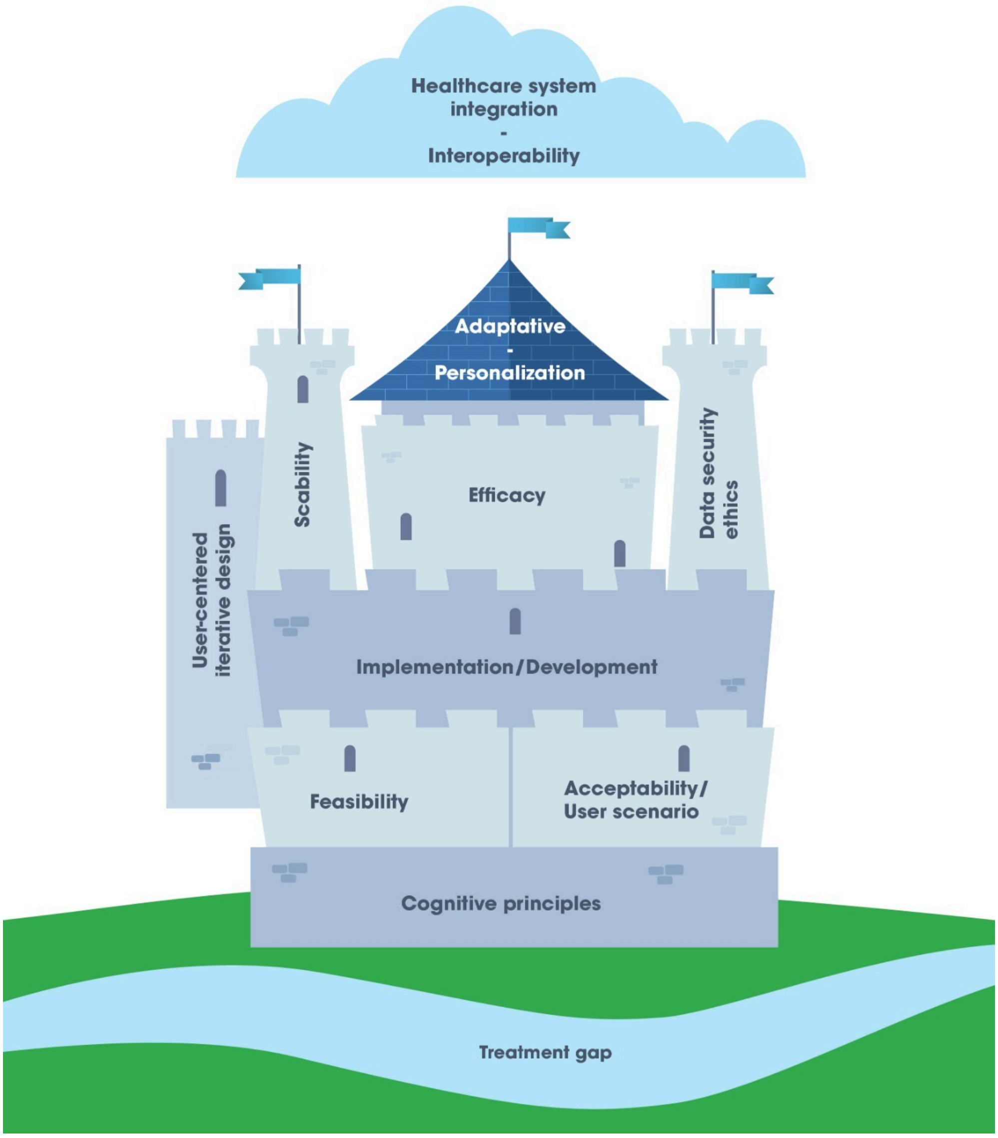


**Figure 1. Different steps involved in the design process**

In a literature review, Alla and Pazos characterized the (1) technological, (2) human, and (3) organizational contexts as key factors that affect robot adoption in healthcare. (1) Design and technical issues, system reliability, and system compatibility represent technological factors. (2) Human factors are trust, perceived usefulness, ease of use, privacy concern, attitude, and confidence towards technology. (3) Organizational factors are represented by legal, security, cost, interoperability, recruitment, and training of manpower relevant to the process  (Alla and Pazos, 2019).

These studies show that designing a technology in healthcare is a complex engineering process. They show the importance of subjective factors like expectancy and organizational factors that need to be considered during development.

### Heterogeneity of users

There are two extremes. Some people could be fascinated by technology, or others could be reluctant and afraid of technology. Both extremes should raise caution. There can be a large mismatch between routine practice and proven evidence-based strategies. Implementation science describes early adopters as opposed to the extreme of the late majority and laggards with different profiles, needs, and motivations (Feijt et al., 2018) and why there is an evidence-practice gap and how to bridge it.

At the beginning of the XIXth century, the Luddite movement was raised because of a fear that technology would replace the workforce among English textile workers. Such reluctance of technology still exists (Jones, 2013) and can be legitimate. In healthy aging studies, older adults fear that the use of socially assistive robots could lead to dehumanized care, in general, in which social isolation of older adults might become even worse, or they may become victims of ageism.

### Digital literacy and Interpretability

The transparency of the device can be limited, which could be driven by technology literacy and poor design. When technology helps in the decision-making during a diagnosis (screening of some disorders like writing difficulties, behavior, or malformation), the professionals need to understand the features used by the system to categorize the disorder. Are the features (semiology to describe the difficulties) interpretable? Is the model (how the features are used to classify the children) easy to understand? Some advanced machine learning techniques can have very good performance but poor interpretability. Using feature extraction and simpler/older techniques like Random Forest instead of deep learning could be better to keep this interpretability (Asselborn et al., 2018) since the model's accuracy can be less important than interpretability. Another strategy is trying to bypass this problem by keeping the advantages of deep learning, especially for image analysis, with a second step to make it more interpretable for the user (e.g., if the model suggests that an image/behavior is suspicious, it shows and describes the region that is considered problematic). This field of research is called Explainable artificial intelligence (Baur et al., 2020; Gunning et al., 2019; Quellec et al., 2021; Xu et al., 2019).

Thinking of synergies between scalable technological needs and specific, face-to-face, and tailored strategies that a human would better handle is more relevant. Technologies can be more complementary to the therapist, especially when they empower him/her (with special sensors, repetitive tasks, and integration of a large amount of data).

### Specificities in children and their family

It seems relevant to target the development of new technologies specifically for children and adolescents. Most disorders appear in childhood/adolescence, in particular neurodevelopmental disorders. In a large-scale meta-analysis of 192 epidemiological studies, Solmi et al. showed that mental disorders were already frequent in children and adolescents with a pick age of onset at 14.5 y.o. (Solmi et al., 2022). The former director of the National Institute of Mental Health in the United States of America goes further by stating that “Mental disorders are chronic diseases of the young.” (Insel & Fenton, 2005). There was a strong debate in the literature about the impact of screens on the development of children, with some concerns that were more ideological than evidence-based (Sanders et al., 2023). Children and younger patients, in general, could be less reluctant to change and use new technologies (Lopez-Morinigo et al., 2021). They grew up with new technologies and can seem more at ease even if they are not technology-literate. Since the brain is more plastic, an early intervention could be more useful. It seems important to focus these efforts, especially in the young population (Doyle et al., 2009). They can have the support of their parents who want to help their children and can, for instance do it by using jointly an app (e.g. relaxation exercises) or a robot in cooperative mode. They could be more creative and more prone to use their imagination. However, since this population is more sensitive, ethics could be more stringent because this brain plasticity diagnosis can change more often than in adults (Caspi et al., 2020).

### Medico Economic studies

We have demonstrated that the demand for technology in psychiatry, especially child and adolescent psychiatry, is substantial. Nevertheless, one significant barrier could be the considerable costs involved, which warrants careful consideration (Christensen et al., 2020). There could be a potential for acceptable and scalable approaches. Since the cost of new technology can be important, it is important to consider the medico-economic approach of a new technological strategy[1]. In the E-goliath-eco study, two tablets are given to the child with Autism Spectrum Disorder and the parent to do imitation and turn-taking activities based on Early Start Denver Model (ESDM) therapy. The ESDM is a well-established therapy. We can expect that the intervention with a tablet will be less engaging and tailored to the needs of the child and his/her parents than face-to-face ESDM therapy. Still, scalability would be much better and could improve the treatment provided by the services as usual.

Hence, design processes and strategies when developing new technologies are complex and require good communication between engineers and clinicians.

## 2. Communication between different worlds: engineers vs. clinicians

### 2.1 Building an Effective Communication between Engineers and Clinicians

Effective communication between engineers and clinicians is essential for developing new medical technologies and devices that meet the needs of therapists and patients. Engineers bring technical expertise, while clinicians bring medical knowledge (how to diagnose, treat, and the rationale) and an understanding of patient needs. When they work together, they can develop innovative solutions that are both effective and user-friendly. However, each group's language and processes can differ, making communication challenging. To overcome these obstacles, it is important to establish clear and open lines of communication, foster a culture of collaboration, and encourage the exchange of information between both groups to ensure the development of effective and innovative medical technologies.

Clear and productive communication and team efforts are crucial in every multidisciplinary work, especially for the success of healthcare projects. To foster this communication, it is

[1] https://clinicaltrials.gov/study/NCT05271955

important for both parties, engineers and clinicians, to take the time to understand each other's perspectives and constraints.

A few articles focused on effective communication between clinical and engineering staff to develop medical devices (Morschauser, 2014; Yoda, 2016). This good communication facilitates the understanding of each stakeholder. While engineers could be interested in solving very defined problems, the problems are only sometimes replicable or well-defined in clinical practice. A doctor's goal is to personalize medicine to the specific needs of his/her patient, which is much closer to craft work than industrial practice. The ultimate model in medical research to assess the efficacy of an approach is the randomized control trial. However, different steps are required before assessing the goal of the device, in which case (user scenario). Based on this best case, is the device feasible?

## 2.2 How to speak to an engineer?

When engaging with engineers, it is important to understand their mindset and communication preferences. Engineers often desire to classify and categorize information, drawing upon their technical expertise and experience to create systematic frameworks (Norman, 2013). Providing clear priorities and assertively expressing needs is crucial to effectively communicate with engineers. Engineers appreciate synchronization between different components and systems and the opportunity to reuse and integrate existing solutions, although this may vary depending on the context (Norman, 2013). Acknowledging what may be useful and important from a clinical perspective can pose technical challenges. Conversely, concepts that seem trivial to clinicians may require considerable technical implementation (Norman, 2013). Furthermore, it is crucial to respect the constraints of clinician and hospital schedules, as time management can greatly impact collaborative efforts. For example, clinicians should consider that a software tool or a piece of hardware requires development time and a lot of testing before it is ready for deployment or applied in a clinical research study. In particular, if engineers are also researchers or professors, technical parts are often conducted in collaboration with students and trainees due to a lack of personnel resources and time constraints. These considerations can lead to additional testing even with participants and patients. Sometimes, this can present challenges as clinicians must explain to participants recruited in a clinical study that they need to return to the hospital for additional sessions because something was not ready or properly tested. This may require ethics amendments and can result in delays. Therefore, involving end-users in a research study's developmental and design phases can benefit everyone, for instance, via focus group meetings, pilot testing, and feasibility studies before running the clinical study. It is crucial to consider the technical deployment in the project timeline of a clinical study, even if it is optional by the Research Ethics Board (REB) offices.

Engage with engineers involves intellectual property considerations, open access strategy, and patents. Engineers appreciate early discussions about valorization and protecting intellectual property rights (Norman, 2013). Additionally, engineers value clean code and efficiency in implementation, as their focus lies primarily on technical aspects rather than clinical methodology (Norman, 2013). However, it is important to note that engineers have diverse technical backgrounds. Furthermore, while some engineers may be more technology-centered, others may possess broader perspectives, especially in robotics

(Lemley et al., 2016; Norman, 2013), or have direct experience with participants and individuals with disabilities, such as rehabilitation engineers.

## 2.3 How to speak to a clinician?

When engaging with clinicians in a research context, it is important to approach communication with an understanding of their mindset and specific needs. Like engineers, clinicians also use specialized jargon, although it may not be the same terminology (Liss et al., 2020; Ryan et al., 2021). To effectively communicate with clinicians, it is essential to start the conversation by addressing the problem first rather than focusing on the technology (Liss et al., 2020). However, the problem is sometimes tailor-made, even if an industrial or a researcher should provide a replicable solution. Taking the time to develop a strong understanding of the needs of clinicians can facilitate better communication and collaboration.

Central reasons behind failures can be listed as follows: "the technology versus human approach" which is adopted by several technical experts and researchers (creating a fear of technology), "technology-oriented design rather than problem-oriented design", and lack of communication of engineers or designers with clinicians, caregivers, and patients". Multiple domain experts and stakeholders of healthcare systems, including occupational therapists, psychometricians, nurses, medical doctors, patient groups, and patients' ecosystem of caregivers, must be involved in every design step as lasting partners in developing and implementing effective technologies.

For instance, technology-oriented approaches are common in the robotics field, where the design process of robotic systems targets multiple user groups without considering the expectations or possible adoption problems (Alla & Pazos, 2019). Within the initial engineering principle, the collaboration between humans and technology should be the leading response. A study for identifying metastatic breast cancer shows that when the intelligent system's predictions are combined with the human pathologist's diagnoses, they get the best prediction results (Wang et al., 2016). We believe new embedded technologies should be designed as tools that will collaboratively support humans. This is particularly important, considering the medical responsibility/accountability an algorithm can not hold.

Due to a lack of communication, the technological solution envisioned by engineers might not serve a real problem. Even if various technologies offered brilliant solutions, they might not be accepted in real environments or natural settings. For instance, in healthy aging studies, older adults fear that the use of socially assistive robots could lead to dehumanized care, in general, in which social isolation of older adults might become even worse (Vandemeulebroucke et al., 2018). This example shows how research might be disconnected from the expectations and perceptions of the targeted group. This kind of technology-oriented approach tends to focus on the functionality of the technology instead of considering its impact on the user's healthcare behavior and potential user resistance (Imms et al., 2016).

Acceptance refers to the extent to which potential users are willing to use a specific system (Vlassenroot et al., 2010), while acceptability is the judgment made before the system is actually introduced. Acceptance is based on the attitudes and behavioral responses of respondents after the introduction of the system. In contrast, acceptability is closely linked with usage and depends on how user needs are incorporated into the system's development. Previous studies (Casas-Bocanegra et al., 2020; Céspedes et al., 2020; Céspedes, Irfan, et al., 2021, 2021; Céspedes, Raigoso, et al., 2021; Cifuentes et al., 2020) have shown that clinicians generally have a positive view of the potential of robotic devices, but lack knowledge about the systems currently being developed. They also expressed concerns about patient confidentiality, cost, and usability. A survey revealed that clinicians consider safety, positioning, movement control, patient feedback, and access to information important features of robotic devices (Lee et al., 2005) . It is important to note that there are different parameters for technology when considering their practicality and acceptability.

Clinicians often need more time due to their demanding schedules and the need for efficient integration of technology into their routines (Liss et al. 2020; Ryan et al., 2021). Special methods to assess usability can be very useful for clinicians, such as using usability questionnaires, as measured by tools like the System Usability Scale (SUS) and user experience (UX), which becomes a critical factor in the successful adoption of technology (Brooke, 1996; Davis et al., 1989; Nielsen, 1994). There are several reasons clinicians might reject a device, such as difficulty with donning/doffing, handling complications, or triggering fear in patients. Therefore, it is crucial to ensure the technology is acceptable and practical \cite{lerdal}. Therefore, it is important to consider the ease of implementation when discussing potential solutions with clinicians. Design guidelines can be very useful to share the best practices in the field (Grossard et al., 2023; Witteman et al., 2021).

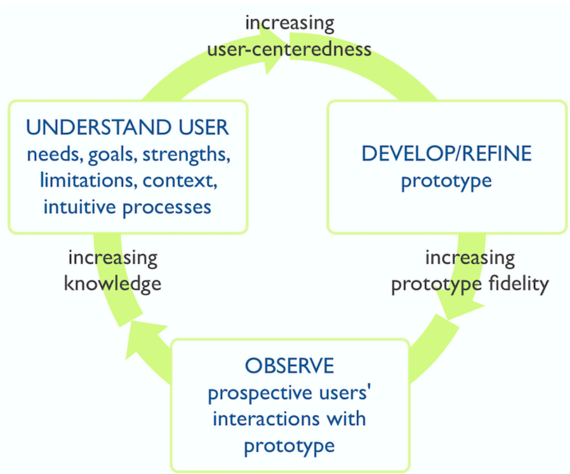


**Figure 2. User-centered design framework in Witteman 2021**


**Figure 3. Items and scoring of the User-Centered Design 11-item measure (UCD-11) in Witteman et al., 2021**

Clinicians bear the ultimate responsibility for the well-being of their patients and are accountable to both the patients and their families (Liss et al., 2020). They must prioritize patient safety and ethical considerations, including data privacy and compliance with regulations such as the General Data Protection Regulation (GDPR) (Ienca et al., 2018). Technology design should consider how, why, where, and by whom a technology is used. Understanding the importance of these ethical considerations and ensuring data privacy and security measures are in place is crucial when speaking to clinicians.

While clinicians may possess a different technical background than engineers, they rely on fundamental sciences like neuroscience and experimental biology, clinical methodology, and evidence-based approaches that are not pragmatic or mechanistic driven (Liss et al. 2020; Ryan et al., 2020). They require coherent integration of new technologies with established care practices and clinical trials, like randomized control trials. Providing interpretable numbers and a basic understanding of the underlying system's cognitive principles (intermediate markers that the clinician can track) and physiopathological models can facilitate their decision-making process (Liss et al. 2020; Ryan et al., 2021).

It is important to acknowledge that clinicians have diverse specializations and areas of expertise. They may have different perspectives and priorities. Collaborating with clinicians from the early stages of research and valuing their input can lead to more successful outcomes. Discussions regarding intellectual property, contracts, and potential valorization opportunities should be initiated early in collaboration (Liss et al. 2020).

In summary, effective communication with clinicians in research requires understanding their time constraints, incorporating usability considerations, addressing ethical concerns, respecting clinical methodology, and valuing their specialized expertise. Researchers can establish fruitful partnerships with clinicians in developing and implementing technology solutions by considering these factors and fostering a collaborative approach.

Regarding using robots in healthcare, there are four important factors to consider for acceptance. Firstly, the robot should not cause harm - this is a crucial design principle clinicians understand well. A training and familiarization phase can be necessary for the professional and the patient using the device. Clinicians understand how long a patient can become accustomed to a new device. They can clarify its goals (C. C. Chen & Bode, 2011) and limits to prevent deception, non-compliance, and disappointment. Secondly, the robot should not induce fear and provide patients safety and comfort. Clinicians can ensure this by understanding the device well and using it accurately during therapy sessions (N. Chen et al., 2020; Conti et al., 2017; Liu et al., 2022). They can also provide empathy due to their experience with patients and their conditions.

# 3. Potential solutions: Design Methodologies

## 3.1 Different levels of users involvement

In the last decades, researchers have developed several technology-enhanced applications in multiple healthcare domains, such as monitoring or assisting the elderly, assisting physical therapy of stroke survivors, and training the cognitive skills of neurodivergent children to contribute to healthcare.

To better understand the needs in the clinical field, it is important to involve end-users in participatory design (sometimes called co-design or cooperative design) (Benton & Johnson, 2015). Anderberg stated that technology and design are “too important to be left only to technicians and designers” (Anderberg, 2005).
The importance of co-participatory design of end users in developing new tech approaches and technologies to support people with disabilities, children, and adults cannot be overstated. Understanding clinicians' and users' needs, expectations, and limits is crucial in the assessment phase.

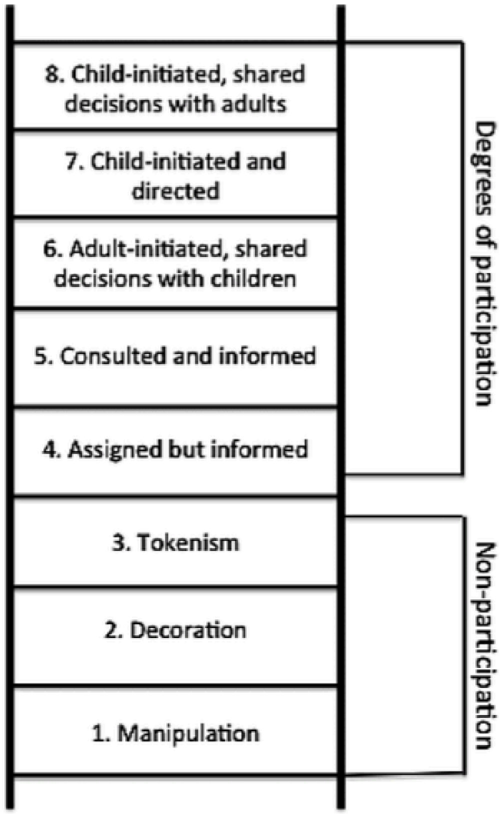


**Figure 4. Hart (Hart, 1992) suggests the different levels of child participation adapted** (Benton & Johnson, 2015).

The most appropriate participation form may vary depending on the project, the children, and resources (Benton & Johnson, 2015). In some studies, the children can undertake several roles (Benton & Johnson, 2015).

In a review about how to involve children with educational needs and difficulties to improve participation in technology design, Benton and Johnson report that Druin (Druin, 2002) identified several levels of child participation: user, tester, informant (that gives input at several points of developments), design partner (they can elaborate on ideas of other children and adults, act as equal stakeholders) and co-designer (Benton & Johnson, 2015). The child's involvement can be indirect (by being observed using the technology, offering direct verbal or written feedback e.g. on a prototype, or engaging more in the design processing while engaging in a dialogue with the adults.
Sometimes, there is a need for a pre-design step, during which the designer takes the role of an anthropologist and moves to the place where the technology can be used in the hospital, in other healthcare settings, at home, in schools), the needs and constraints in the field. Children and adults seek inspiration from each other's ideas during idea elaboration. "This inspiration is then used to create new ideas or design direction as well as build directly upon another participant's idea, where "ultimately it may be difficult to remember whose ideas they were originally"(Benton & Johnson, 2015, citing Guha et al., 2013). This engagement can benefit the participant who can enjoy himself, feel empowered, take more responsibility, feel competent, develop teamwork, and learn social or creative skills (Benton & Johnson, 2015).

However, there are debates on how technologies fail to adopt or fulfil the demanded actions envisioned by engineers (Alaiad & Zhou, 2014; Alla & Pazos, 2019; Stahl & Coeckelbergh, 2016).
Sierra Marín et al., 2021 investigated the expectations and perceptions of healthcare professionals regarding robot deployment in hospital environments during the COVID-19 pandemic, highlighting the significance of involving clinicians in the design process. Similarly, Raigoso et al., 2021 surveyed socially assistive robotics. They found that clinicians' and patients' perceptions play a vital role in successfully integrating a social robot within gait rehabilitation therapies.

Moving into the deployment/implementation phase, Casas et al., 2019 emphasized the importance of aligning expectations with reality regarding attitudes towards a socially assistive robot in cardiac rehabilitation. Additionally, Múnera et al., 2022 explored clinicians' experiences using rehabilitation robotics, emphasizing the value of incorporating their insights in refining and improving the technology. By involving end users and clinicians throughout the design and deployment phases, we can create technologies that effectively meet the needs and expectations of those they aim to support, ultimately leading to enhanced outcomes and improved quality of life.

**How to reach the design of a technology with a participatory approach**

To incorporate a participatory approach, the end users should be seen as experts, rather than as subjects or participants in studies. Technology itself is not the solution itself since there are multidimensional complexities in each healthcare environment. Therefore, fast prototyping (minimum viable product) and in-the-wild testing are necessary to observe and understand these dynamics. Moreover, the design should facilitate high adaptability, personalization, and customization, tailored to the specific dynamics of each environment and the relationships between various stakeholders involved.

Creating engagement and fostering involvement are crucial goals in designing any activity. Several environmental dimensions affecting the engagement and involvement of users are identified in literature as follows (Imms et al., 2016; Maxwell et al., 2012):

• **Availability**: Objective provision of activities and services, including time of use and frequency of attending the activity.
• **Accessibility**: Ability or the perceived ability of the stakeholders to access the activity or situation. Including perceived accessibility of a situation and the more objective possibilities a person has to access the situation.
• **Affordability**: Resource constraints to the activity, including financial cost, time costs, and energy costs. An activity having less resource cost will potentially have a higher reach, impact, and adoption.
• **Accommodability**: The ability of the situation to be adapted or modified. Modifiability of an activity to be adjusted, changed, or customized to suit different needs, situations, or preferences.
• **Acceptability**: The affected person's and other people's acceptance of the activity and its situational context. Including the person's acceptance of the situation and other people's acceptance of the individual in the activity setting. It could be important to conduct simulation phases with users and focus groups to assess these questions during the design phase or at

least before an efficacy trial. Specific guidelines to report qualitative research exist like the COREQ (Tong et al., 2007) or SRQR (O'Brien et al., 2014) guidelines.

Due to this multi-dimensionality, designing technology-enhanced solutions for multiple ecosystems becomes more complicated. Although the provided solutions should be adaptable to multiple factors, what should be adapted and what to adapt for need to be clarified within these complex environments. Therefore observational experiences within multiple healthcare environment with patients with ranging profiles is crucial for the design and successful integration of new technology in such environments in a more sustainable way.

Designing technology-enhanced activities within therapy sessions presents numerous challenges and uncertainties. These include managing the arrangement of activities, utilizing space effectively, and determining the composition of groups comprising children or patients with diverse learning goals and varying physical and cognitive capabilities, particularly those with special needs. Considering these complexities, envisioning a traditional study setup or a singular ideal solution for developing and testing a functional design to demonstrate positive learning outcomes becomes impractical (Rosner, 2018). Multiple setbacks and learning experiences arise, necessitating active engagement with stakeholders to refine the current design and enhance its functionality and flexibility to cater to patients facing different challenges

Due to these factors, apart from following an iterative design methodology where the system is tested and improved repeatedly at different stages of maturity and practicality, the studies should be implemented in the wild in their natural settings to consider the different contexts and complexities of these specific ecosystems. Throughout each cycle of refinement, the improved design must undergo thorough verification to identify weaknesses and collect insights and feedback that can assist in further enhancements and adjustments for integration into various settings.

Several lessons learned can be drawned from the wild therapy ecosystems (Guneysu et. al., 2023). Some of the observational insights are as follows:

- Allowing the therapists to intervene the interaction between technology and the patient is crucial. The technological solution for therapy should not exclude the therapist and might need to allow therapists to intervene in the therapeutic activity (Accessibility).
- The design targeting young children, particularly those aged 3 to 5 years-old, should prioritize the incorporation of simple rules or possibly provide unstructured free play. (Accessibility).
- Computer-Human interaction studies should go beyond using engagement scales with robots or technologies in activities that target functional training, especially for younger children who might refuse to use the technology (Acceptability).
- Children's perception of technologies (especially robots) influences their behavior, interaction, and expectations on the role and capabilities of the system (Gargot et al., 2023, Rubegni, E. et al. 2022). This might affect the learning goals or therapeutic output. For instance The design of verbal, visual, and motion-based feedback should account for the perception of children below 5 years old (Guneysu, A., & Arnrich, B. (2017)). This includes understanding how much attention they typically allocate to

each type of feedback mechanism or to the overall system (Olsen, J. K. et al. 2022). Additionally, considering their limited comprehension of virtual or visual elements is essential in creating effective feedback systems (Accommodability).

- Robots or new technologies might not serve multiple purposes and learning goals of a complex therapy or learning environment. They are just tools that might be integrated as 'one alternative' into the natural activity flow and structure of the current ecosystem. Therefore, such technologies
  - require to allow integration of traditional practices into the activity flow
  - need adaptation of activity content according to the schedule, current methodology, and objectives of the therapists/psychologists (Accommodability)
  - need ease of set-up for the unique room settings and change of rooms within a limited time (5-10 minutes set-up time) (Affordability)
  - Also, the duration of the technological activity has to be adapted to the attention levels of the children and the therapy duration (Affordability). This limited duration of practice sessions (30 or 40 minutes) and the limited space available in therapy centers and schools (Availability) are important factors to be considered in the design (Guneysu Ozgur, A. et al. 2020).
- Studying the potential impact of technology on group dynamics is crucial for group therapy, along with examining how different roles assigned to robots might influence children's behavior. Additionally, it's essential to explore how group dynamics can influence the overall interaction between children and technology (especially robots). During the design phase, it's important to account for elements like peer pressure, the need for peer approval, and the tendency to imitate peers. These factors can significantly impact how children interact with and respond to the designed elements, particularly in social settings or group environments (Guneysu, A. et al. 2013, Guneysu Ozgur, A. et al. 2020). In group therapy, systems targeting multi-child systems should account for the fluctuating or dynamic changes in the number of children involved. To accommodate the varying number of children from one session to another, the design approach could involve creating adaptable setups with a flexible number of robots working simultaneously. Alternatively, it could focus on crafting activities that allow multiple children to interact synchronously with a single robot or participate together in a game (Accommodability).

These insights play a significant role in shaping the design of new technology for therapy, taking into account various facets of diverse care environments. Adapting the design and elements of a technology-enhanced activity to suit different user groups and settings, enhances the potential for integrating such systems into various care environments in a sustainable manner.

## 3.2 User-centered design

User-centered design is a fundamental approach that emphasizes the active involvement of end users in the design and development process of new technologies. This chapter section explores the importance of customization for specific populations and contexts, recognizing that users' needs and preferences can vary greatly. It also highlights the significance of user participation and the use of various participatory design methods to create inclusive and effective solutions (Benton & Johnson, 2015). The concept of *informant design* was coined to involve more actively the users in the design process, the goal of *Experience-centered design* is even to think about how to engage as much as possible (Benton & Johnson, 2015).

Designing for different populations and contexts requires a deep understanding of their unique requirements and challenges. For instance, the needs of children with disabilities may differ significantly from those of adults. Moreover, the environment inside a hospital setting may present distinct considerations compared to the outside world. Recognizing these differences is crucial in tailoring technologies that truly address the specific needs of the target population.

To achieve customization and user-centeredness, a range of participatory design methods can be employed. Visual templates, drawing materials, games, sculptures, and narrative-based participatory methods can facilitate user engagement and the expression of their preferences and ideas (StudioLab, n.d.). Additionally, simulation and roleplay techniques can help users envision the potential impact of the technology in their daily lives.

Participation goes beyond individual users and extends to the involvement of the community and relevant associations. Engaging stakeholders who represent the target population helps to ensure that the design process reflects a broader range of perspectives and experiences. By including community members and associations, the design team can gain valuable insights and create contextually appropriate and meaningful solutions to the end users.

Measuring the success of user-centered design efforts is also important. The development and validation of measures such as the User- and Human-Centered Design for Personal Health Tools (UCD-11) provide a framework for evaluating the effectiveness of user-centered design practices (Witteman et al., 2021) (Figures 2 and 3). These measures help assess the extent to which the design process prioritizes user needs, preferences, and usability. For instance, during the development of the “oto chair”[2] that allows to perform deep pressure on children with autism, several version of a prototype were designed. The use with psychomotricians and end-users like children with autism and intellectual deficiency allowed researchers to design an easy and simple interface. A small light on the remote control that could be sensory stimulating was suppressed after these tests, and the noise accompanying the inflation and deflation was decreased.

A good animation of such design sessions is important, especially in children groups, particularly when they may have special educational needs and disabilities. According to Benton, the role of adults is (i) to ensure the children’s well-being, (ii) to encourage every opportunity to engage in activities they want to, (iii) to provide the support and environment so the children can feel empowered whenever possible, (iv) provide an environment to foster mutual learning, (v) creating an experience that is positive enough to encourage them to repeat the experience.

In conclusion, user-centered design with customization for specific populations and contexts is a time-intensive yet essential approach. Incorporating participatory design methods, involving the community, and utilizing validated measurement tools can enhance the

[2] https://www.oto-chair.com/

effectiveness and inclusivity of technology solutions. By prioritizing the active engagement of end users and considering their unique needs, we can create technologies that positively impact their lives.

# 4. Conclusion

There is a great treatment gap between the needs and what the healthcare system can provide. New technologies offer interesting opportunities in mental health and in the healthcare system in general. It is important to develop and apply good practice and good evidence to have clear cognitive principles on which to build upon new technology, for instance, the Cognitive Behaviour Therapy principle, feedback loops, flow theory and proximal zone of development and gamification in serious games (see Figure 1 for the different development phases). It is important to know precisely when the technology intervenes and how (what is the user scenario? Is it acceptable?).For instance, in an iterative design process of a writing serious game, we measured handwriting improvement before and after the robot activity within an occupational therapy context (Gargot et al., 2021) while adapting the system into multiple occupational therapy environments which demanded variants of adaptations throughout the iterations. Parallelly, it is important to assess technological feasibility based on needed resources. After these steps, it is important to begin a user-centered design in the field (Witteman et al., 2021). The implementation and development can begin. Once the technology is mature (see for instance, the Technology readiness levels (Mankins, 1995), it is time to assess the efficacy. The design can continue with new usage. These technologies can offer new possibilities in terms of scalability to reduce the treatment gap but also raise new challenges about data security and ethics. The adaptation and personalization of the system to the specific needs of the patient and the context will need to be considered. In a complex system like a healthcare organization, the last steps would be integrating the new device with pre-existing technologies and allowing proper communication between these systems.

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