Bringing aesthetically-minded design
to devices for disabilities

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ABSTRACT
Can therapeutic and rehabilitation aids be engaging and pleasurable to use? Can disability be seen in terms of aesthetically-minded design rather than only in terms of accessibility legislation? The paper explores the role that design could play in reducing the stigma associated with the use of rehabilitation aids that inherently manifest impairment and the inconvenience of the disability condition. The design case described in the paper shows that rehabilitation aids can be engaging, useful and pleasurable to use.

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Design approach, Special needs, rehabilitation, social relations

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H5.m. Information interfaces and presentation: Miscellaneous.

INTRODUCTION
There is huge potential for innovation in the rehabilitation practice and care of disabled people. Nowadays technology offers a full range of possibilities, from innovative prostheses to monitoring systems, from e-health care to augmented rehabilitation. Most of these technologies may have reference under the big umbrella of accessible and assistive technologies. A fundamental issue for the development of such technologies is to design for both accessibility by impaired people and effectiveness of the therapy [1]. These technologies mostly refer to the concept of “cognitive orthoses” or “cognitive prosthetics”, that is compensatory strategies that alter the patient’s environment and are directed to an individual’s functional skills [2].

In this paper we present a design case that takes a different perspective in the design of rehabilitation aids. The approach emphasizes engagement and gratification in therapy with the goal of making therapeutic devices pleasurable to use while maintaining their value and efficacy as therapeutic aids. The ultimate goal is to counteract the impression of inconvenience of the disability condition that many rehabilitation aids inherently manifest and to exalt the beauty of interaction and satisfaction of recovery. We believe that design can balance the tension between a functional approach to accessibility and a more playful and aesthetic exploration of technologies supporting disabilities.

The idea that design sensibilities can be applied to therapeutic aids and that in return disability can provoke radical new directions in mainstream design is witnessed by famous and outstanding design cases.

In Design Meets Disability, Graham Pullin [3] shows how design and disability can inspire each other. By discussing insightful design cases, he states that disability can force some new questions onto the agenda that can actually open up new ways of thinking, and not just in terms of better accessibility.

On a similar mainstream, even if from a different disciplinary viewpoint, Cairns and Thimbleby [4] argue that disability in HCI is a source of richness, being HCI called to respond the question “can digital technologies, in all their forms, help their users have a better experience?”. Harper et al [5] recommend that human values, in all their diversity, be better understood and charted in relation to how they are supported, augmented or constrained by technological developments.

In this paper we present a design case of an interactive system called Rolling Pins (RPs) developed to stimulate dementia affected people to empathically communicate with therapists and care givers. The valence of the aesthetic experience with the RPs is not correlated to the appeal of the system components but to the quality of interaction and
the emotional tuning among people that is sustained and mediated by the system. The aesthetic experience lies primarily in the interaction and the way in which the system behaves and responds over time in interplay with the users [6].

THE AESTHETICS OF INTERACTION

The field of Aesthetics of Interaction has reached a certain maturity, partly consolidating the idea that in response to a change in the use of computers and interactive technologies, traditional HCI concepts of usability, efficiency, and productivity have to be enriched with other values such as curiosity, intimacy, emotion and affection. This is done in part through the development of new models and theories that explore many different directions and methods of technological implementation [7]. In the last years, different views have emerged that contributed in various way to the definition of a theoretical framework of Aesthetics of Interaction. One view understands the notion of aesthetics as being a result of the appearance properties of form as perceived visually [8]. Here, aesthetics is seen as an added bonus pertaining to the object apart from the context of use. According to this view, the judgment of beauty is a higher-level evaluative construct which is independent of the actual product-usage experience. However, satisfaction and pleasure are emotional consequences of goal-directed product usage. Other views consider aesthetics with a socio-cultural connotation, as the appreciation of different components (materials, forms) and properties that do not inherently pertain to the object itself [9]. Other views of aesthetics introduce the concepts of Resonance [10] which inspired the design case described below. The concept of resonant interaction is derived by the gibsonian theory of ecological or direct perception. Gibson [11] used the term “resonance” to mean the active engagement of a person with her environment, shown by actions spurred by perceptions. However, resonance does not only relate to perception and perceptual-motor skills but to our cognitive, social and emotional skills too. In the design case described below, the concept of resonant interaction is explored through the development and testing of a therapeutic system that mediates patient-therapist interaction by enabling perceptual-motor and social dynamics of resonant interaction.

THE DESIGN CASE

Several studies have shown the importance of social relations in preventing cognitive and behavioural decline in elderly people. Along a 12 year longitudinal study involving 2812 non institutionalized elderly persons, Bassuk and colleagues [12] provided evidence on how social disengagement is a risk factor for cognitive impairment among elderly persons. They explain their findings stating that social engagement can prevent cognitive decline and that people must maintain social skills, the ability to communicate, and the ability to sort out complex interpersonal situations. These results have a direct implication on the definition of therapeutic interventions: if elderly persons are actively provided with opportunities for communicating, exchanging, collaborating and being engaged, their cognitive abilities will remain more intact.

As said in the introduction, one of the motivations of the project was to apply design sensibilities to the development of therapeutic aids and to look at disability as an opportunity to provoke new directions in mainstream design. In doing this, we wanted rehabilitation aids to be both poetic and practical, engaging and useful, to try to reflect the inherent beauty and satisfaction of recovery and wellness.

Our view of aesthetical interaction was based on resonant interaction, choreographic movements, empathic relations, and embodied playful exploration as pivotal concepts for design. Inspired by the stereotypical movements of dementia affected people, we wanted to stimulate them to use these movements to explore expression modalities, establish empathic relations and create a shared communication code with the therapist. We believe that embodied explorations can arise self and social awareness and promote shared intentionality. They can activate opportunities to act in coordination and communicate beyond words.

In what follows we describe the design process we adopted and the challenges we met in bringing aesthetically-minded design to the development of the RPs, interactive objects designed to scaffold dialogic exchanges between the therapist and elderly people with relational disturbances.

A fundamental effort was devoted in understanding our users, their needs, their residual abilities (both cognitive and physical) and transforming them into requirements driving the design process.

USER STUDIES

Dementia subjects suffer from an acquired permanent neurodegenerative disorder that affects the global functioning of the individual, progressively impairing cognition, personality and behaviour. In particular dementia is strongly characterized by social isolation and difficulties in communication. Speech becomes increasingly inefficient and progressive short-term memory difficulties and problems with new learning make conversations and other social interactions problematic [13]. Consequently, most people become reliant on caregivers to initiate engagement and interaction, and to take care of everyday living activities and arrangements. The social sphere of the individual is jeopardized not only by the impairment of social abilities resulting from global functional impairment of the subject but also by the patients withdrawal from social interaction due to a number
of contextual factors ranging from aural and visual ability impairment, institutionalization and interpersonal disorientation, lack of self-esteem and low motivation.

**Analysis of residual abilities**

An initial difficulty in defining a framework of key characteristics of dementia is that the clinical course of this disease is characterized by the progressive manifestation of cognitive and behavioural symptoms. However, the definition of a univocal progression of the cognitive symptomatology is problematic: the degree and the temporal manifestation of the impairment are different for each, individual patient. Nevertheless, it is possible to identify some commonalities across the different, individual cases [14].

Generally, the first symptoms to appear are episodic memory deficits and the related difficulties in remembering recent events. However, the implicit system (procedural memory) has been shown to be relatively well preserved until the later stage of Dementia: some authors [15] claim that implicit memory rehabilitation - that is the automatic acquisition of verbal and non-verbal knowledge or skills (procedural knowledge) - can improve or maintain the abilities for specific basic or instrumental activities to be carried out in daily living. For what concerns the attention, we can state that the ability to focus on two or more stimuli (divided attention) at one time is impaired early on. However the ability to screen out irrelevant stimuli or the continued focus of attention on a task over unbroken periods of time (sustained attention) are all compromised much later in the course of the disease. Since dementia affected patients lose the ability to retain and process complex stimuli, they experience an increasing difficulty in making sense of the external world. The progressive impairment in codifying, elaborating and integrating information, in the explicit modality, can be considered as a common characteristic among the different clinical courses. However, dementia does not affect the peripheral cognitive system: indeed, fine-motor abilities (manipulation) are not compromised by the syndrome and the execution of automatic sensory-motor routines is not affected by the deficit. Finally, language functioning may be relatively spared in the early stages of the disease, but it is likely to decline substantially in the mid to late stages.

A model of residual abilities

Figure 1 shows a model of the progression of the cognitive decline in relation to the cognitive functionality elaborated with geriatrics and therapists during participatory design sessions. The value of this model is not to be held rigorously to the actual progression of the syndrome (values do not have well defined boundaries); rather it permits the immediate appreciation of the abilities which are not impaired by the dementia syndrome (orange dots), a set of abilities that are impaired only in the later stages of the illness (green dots) and a set of abilities that are immediately affected and impaired (black dots). This model represents the first reference framework of the conceptual design.

More specifically the abilities marked as red dots constitute the parameters for the definition of an interaction model based on a set of familiar and consolidated sensory-motor patterns that if appropriately stimulated can be learned by the patients. The green dots are the abilities that the system should scaffold, for example driving the patient’s attention among selected stimuli. The black dots identify abilities which are the most compromised: the design should try to minimise interactions involving these abilities.

![Figure 1: Model of residual abilities](image)

In light of these considerations two key principles guided the definition of initial requirements:

1. Patients affected by Dementia refrain from exploring novel situations since they perceive their competence as not sufficient. The patient should be stimulated to start the exploration of the system on a “safe” and familiar base. Engagement in the activity is fundamental to stimulating exploration and getting involved in the therapy.

2. Considering the limited cognitive resources of a dementia affected patient, the system should be able to capture and maintain the attention of the patients without directly affecting the cognitive load.

**From residual abilities to requirements and design challenges**

In order to meet these principles a set of features/requirements for the future system has been defined by expanding and elaborating the design space identified in the residual abilities model (see figure 1). Requirements were stated at a conceptual level with the specific aim of merging them with the concept design phase, and with the idea that only after their match with the
concepts would they be refined in functional terms. The requirements were not produced as a list, but as a conceptual map where the landscapes were defined by key values of the future system.

**Manipulation**
Gross-motor physical limitation advocates for a limited interaction space populated by objects whose dimensions and weights are suitable for an easy manipulation.

**Naturalness**
Because of the difficulties in making sense of novel and complex situations, it is fundamental to design very simple and clear interaction modalities based on physical and sensorial manipulation.

**Familiarity**
In order to exploit residual abilities related to procedural knowledge, the system should be able to stimulate consolidated and familiar sensory-motor patterns.

**Focus of Attention**
Irrelevant stimuli should be considerably reduced in order to avoid the dispersion of the limited attention span of patients. At the same time, the patient’s attention should be driven by relevant stimuli.

**Responsiveness**
Patients affected by dementia have trouble understanding cause/effect relationships. For this reason it is fundamental to provide an immediate feedback to the patient’s action close to the input zone. Furthermore, the system’s response should persist until the action is performed over the system. In other words, if the patient does not operate on the system the system should remain idle.

**Multi-sensorial stimulation**
The system should stimulate all senses: sight, hearing, touch and smell. The therapist will decide how to administer and control the stimuli during the activity.

**Adaptivity**
Because of the differences among the patients, in terms of residual skills and therapeutic objectives, the therapist should be able to adapt the system to the needs of each single patient by using the same set of tools and services.

**Scalability**
The system should provide the therapist with the possibility of controlling the quantity and the quality of the stimulation. The therapist should be able to define different configurations of stimuli and their progression (e.g. remove progressively some stimuli to scaffold the acquisition of a specific skill).

**Non Verbal Dialogues**
Due to the difficulties that patients affected by dementia have with verbal communications, the system should sustain non verbal dialogues.

Figure 2 shows the mapping between requirements and cognitive/physical abilities of patients suffering from dementia. System requirements have been largely discussed with therapists and geriatrics that supported us in envisioning therapeutic activities enabled by a system that meets such requirements.

Therapists considered the following three activities as fundamental to the definition of therapeutic protocols aimed at stimulating social exchanges:

- **Imitation-based activities** based on non-verbal interactions, intended to counteract isolation and stimulate exchange and coordination.
- **Activities implying joint attention**, a pre-requisite for the emergence of imitative patterns is joint attention. The patients and the therapist should join their attention on the same activity objects.
- **Motivating activities**: The active involvement of the patient is a fundamental aspect for a successful therapy. It is important to avoid a mere repetition of sensory-motor patterns or mechanic responses.

Figure 2: Mapping between cognitive capabilities and system requirements. This figure presents a detailed elaboration of the design space presented in fig. 1 (the same color code has been adopted): it is possible to observe how each requirement addresses a specific subset of Residual Abilities. For example, the requirement Familiarity is intended to minimize the involvement of Ideomotor abilities (which are early compromised) in the interaction with the system (black dots), to actively scaffold Procedural Memory and Manipulatory abilities (orange dots) and to exploit ideational abilities that are longer preserved (green dots).

**CONCEPT DESIGN**
The design phase is unique for the fact that it is continuously fed by a concept generation activity. In this phase, often defined “simulate to stimulate”, we developed scenarios of use and re-conceived the qualities and the attributes of the system. The concept generation phase allowed a constant flow of innovation into the design process, going beyond the mere interpretation of user needs to stimulate the demand of functionalities that could
improve and transform the way in which the therapists carry out their activity. Geriatrics and therapists were constantly involved in the process even if a pure creative phase of concept generation was carried out independently by the design team and within the design team.

Out of necessity, this kind of approach generated an extraordinary diversity of ‘components’, technologies and concepts. We report hereafter two examples of the generated concepts.

**Sense Ring**
Sense ring (see fig. 3, C) is a system composed of coloured soft and deformable rubber rings. Each ring is divided in 8 sections in which a pressure sensor and a vibration actuator are placed. Each section is independently functioning system able to receive input (pressure), integrate the information coming from the other sectors and actuate a local output (vibrate) or an ambient output (light changing or sound). Each section is a module with its own characteristics configured by the therapist at the beginning of the therapy session. Aural, visual, tactile and auditory feedback can be associated to each sector. The ring is held by the user and the therapist together to create a collaborative sensorial.

**I-Egg**
The I-Egg (see fig. 3, B) is a system composed of spherical units that can be detached to produce a visual, auditory or tactile feedback. The feedback is modulated by physical manipulation. When the i-egg is opened the volume of sound, the intensity of the light or the vibration increase or decrease depending on the distance among the two halves.

**Rolling Pins (RP)**
The RPs are semi transparent cylinders capable of measuring their orientation and the speed of their rotation. At a local level they have three types of feedback: RGB light, sound and vibration. The peculiarity of the RPs is that they are able to communicate with each other. They are used in pairs by two actors (typically the therapist and the patient), and the local feedback of the single RP can be set depending not only on its own speed and orientation, but also on the speed and the orientation of the peer RP.

The RPs embed by design a concept of reciprocity, coordination and resonant interaction: the local feedback of each RP depends on the operations synchronously performed on the two pins. Therefore, the local feedback of each RP can be a function of the sum of the speed rotation of both RPs; potentially, it can be a function of any other operations between the speed rotations and orientations of two RPs.

The therapists assessed all the developed concepts. Frequent, small, informal evaluation activities iteratively improved the design. The evaluation was continuous and as closely and authentically related to use as possible. Concepts, ideas, scenarios, prototypes and evolving work practices were continuously examined to ensure quality and appropriateness to the concepts [10].

Figure 3 shows the mapping between the concepts, the therapeutic activity and the system requirements as defined in the previous phase. Since the RP were more likely to meet the majority of activities and system requirements, this concept was implemented.

**Figure 3**: Mapping between concepts and requirements. The size of the circles shows the extent of the opportunity space that each concept offers in respect to the requirements.

**TECHNOLOGY DESIGN**
A RP consists of a semi transparent plastic tube with solid end caps of black sandblasted plastic (see figure 4). All the electronic components are placed on one large PCB inside the tube [11]. The RP has a length of 300 mm, a diameter of 50 mm, and a total weight of 350 gram including batteries.

**Figure 4**: Rolling Pins

The RP has three types of feedback available: RGB light, sound and vibration. Furthermore RPs are able to communicate with each other and with similar devices equipped with the same radio communication technology. The RPs are capable of measuring their orientation and their speed of rotation.

The software framework for the RPs allows the applications to run autonomously in the tools, while however also providing the possibility for communication with a host PC [16]. The PC software is responsible for the
control of application selection, thus allowing the user to select an application for usage. The PC side of the application consists of an easy to use GUI which has the capabilities to plug in the different applications. The therapist can set the programs for the tools, this information is then collected in a transmission package, and sent from the PC to the base that broadcasts the message via its radio transmission.

The RPs are specifically designed to support resonant interaction and empathic exchanges between the therapist and the patient, providing them with the opportunity to establish a “pragmatic dialogue” based on visual, aural, tactile and sensory-motor interaction modalities. The RPs embody a dialogic component supporting non verbal communication between therapist and patient. The RPs create a shared interaction space where the therapist has different opportunities to influence the patient’s behaviour by showing specific sensory-motor interaction patterns with the RP and simultaneously affecting the feedback of the RP held by the patient.

In order to support rehabilitation activities in a playful and aesthetically pleasant way we have identified three ways of using the RPs: individual (no communication between RPs, the activity is mainly based on the reciprocal observation of the behaviour), transmission (RP1 modifies the response of RP2 but not its own feedback and vice versa) and dialogic (the local response of each RP depends on the synchronized manipulation of both RPs).

Different opportunity of coordinated “choreographies” can be obtained using the RPs. For example, in the “mirror” application (Manipulation: tilting, Stimuli: vibration, Communication: dialogic exchange) a RP can vibrate whenever it moves at a different speed from its peer. The task of the patient is to match the therapist’s rotation speed to stop the vibration. The therapist can choose the vibration as a single feedback or reinforce the output with a visual or aural feedback. The particularity of this task consists in its dynamic nature: the therapist can decide to slow down the rotation speed in order to facilitate the patient in the synchronization or can decide to make the task more difficult to execute, by deliberately challenging the synchronization, moving the RP at different speeds and rotation patterns; in other words, the therapist can adapt the task complexity during the task itself. The opportunity to continuously adapt the difficulty of the task to the skill of the patient is fundamental to the creation of an optimal experience so that the therapist and the patient can resonate each other.

FIELD TRIALS

The RPs were tested for several months in exploratory field trials. 12 randomly selected patients who had received a MMSE (Mini Mental State Examination) score ranging from 16 to 27 (moderate cognitive impairment), were involved in different activities ranging from the execution of structured sensory-motor patterns initiated by the therapist, to the free exploration of the RPs [17].

We designed an experiment to compare the use of the RPs under two conditions: individual modality vs. dialogic modality. In the configuration for the Individual modality, four different rolling speed ranges have been identified. When the rolling speed of the RP is within the boundaries of a certain range, it provides specific visual and aural feedback. In the dialogic modality the two RPs communicate with each other: in the specific implementation adopted for the experiment, the local feedback of each RP is given by the sum of the shift frequency of the peers.

Figure 5. Mapping of shift frequency ranges and colours in the individual modality (left) and in the dialogic modality (right).

For example, whenever the sum of the shift frequency of two communicating RPs is within range A, each peer will show the colour blue and will generate the tone C4. As the sum of the shift frequency increases, the colour changes from cold to warmer tonalities and the tones become higher; when it reaches the highest value, both RPs start vibrating to reinforce the feedback. In Figure 5, it is possible to observe the difference between the two programs in terms of mapping between shift frequency ranges and colours. It is important to notice that the full range of feedback can only be experienced if both the therapist and the patient are involved in the activity. In fact, if the therapist does not move his/her own RP, the patient can only reach the shift frequency values from range A to range E/F.

In conclusion, under condition Dialogic Modality the RPs communicate with each other (Communication: dialogic negotiation; the local response was given by the sum of both RPs’ rolling speeds). Under condition Individual Modality, RPs were used as single devices, fully interactive but not communicating with each other (Communication: individual). Each patient was randomly assigned to an experimental condition and we obtained two equally numbered groups: a group working in the Dialogic modality and a group working in the Individual modality.

The activity protocol for each subject included two main phases: Phase A has been designed to understand whether or not the Dialogic modality stimulates autonomous initiative in the patient participating in the activity, without
any additional instruction from the therapist. Phase B has been designed to observe the patient’s behaviour in a dynamic coordination activity. Each session was video-recorded and a video-analysis was subsequently carried out.

The analysis of Phase A shows that every subject but one working in the Individual condition did not autonomously reproduce any interaction pattern proposed by the therapist; instead, for what concerns the dialogic condition, 4 subjects reproduced every interaction pattern proposed by the therapist. Data coming from the behavioural analysis of phase B indicates that in the Dialogic condition patients were tuned with the therapist for a significantly longer time than in the individual condition. Furthermore, differently from the Individual modality, in the Dialogic modality patients spend most of their time imitating the therapist’s sensory-motor patterns rather than producing random behaviors [17].

These results suggest that the dialogic modality favours the emergence of a sensory-motor coordination between the patient and the therapist within a shared interaction space. A qualitative analysis of the movements performed by the therapist and the patient during the Phase B (dynamic coordination) of the Dialogic Condition has revealed the emergence of recurring choreographies as shown in figure 6 and 7. In particular in Figure 6 the patient and the therapist oscillated the RP from left to right, with a wide and calm movement; in Figure 7 they made fast circular movements, mirroring each other. Once acquired by the patients, both choreographies and repetitive patterns were used by the patient to communicate his inner emotional state. In the interpretation of the therapist, the patient took the initiative to pass from the oscillation to the circular movement to express different feelings during the session, from relax and enjoyment (oscillating movements) to anxiety and effort (rotations).

Figure 8 shows a different example. At the beginning of the session, the patient and the therapist rotated their RP on the opposite sides of the table. After a while, the patient started to perform a wider movement, reaching the side of the table where the therapist was performing her movement. The therapist decided to imitate the patient and they started rotating their RP at the centre of the table very close to each other obtaining the same sound and light. The patient enjoyed to be in control of the choreography and kept taking the initiative of smoothly proposing new movements in coordination with the therapist. The therapist interpreted this behaviour very positively, as a sort of empathic tuning implying communication, coordination, shared intentionality.

The use of the RPs promoted a communicative ecology reducing isolation and motivating communication and participation beyond the verbal exchange. Different studies [18] have demonstrated the importance of sensory-motor imitation and hand-eye coordination in facilitating social relations in people suffering from relational disturbances (in particular people affected with autism and dementia).

![Figure 6](image6.png)

**Figure 6.** The therapist and the patients were synchronized in oscillating their RPs.

![Figure 7](image7.png)

**Figure 7.** The therapist and the patients were synchronized in rotating their RPs.

![Figure 8](image8.png)

**Figure 8.** The patient takes control of the choreography.

**CONCLUSIONS**

The trials performed so far cannot still provide fully validated results to evolve the exploratory use of the RPs in therapeutic protocols for people suffering from dementia. However they provide insightful evidence of their potential...
to counteract isolation and promote social exchanges in people with relational disturbances.

More interestingly for the purposes of this paper is that the design case of the RPs can be regarded as a concrete example of how a functional approach to accessibility can be effectively re-thought in terms of a more playful and aesthetic exploration of technologies supporting disabilities. Moreover, the design case shows a range of design challenges inspired by disability; many of these sound niche at first, but we believe they have broad potential and a larger applicability in other domains.

By observing the relations between patients and their care givers we understood that the therapy is effective if culturally sensitive, and emotionally sensitive. These values are lost during the therapy if a functional approach prevails. An aesthetically-minded design can favour the re-appropriation of such values and restitute dignity and naturalness at the therapeutic intervention.

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