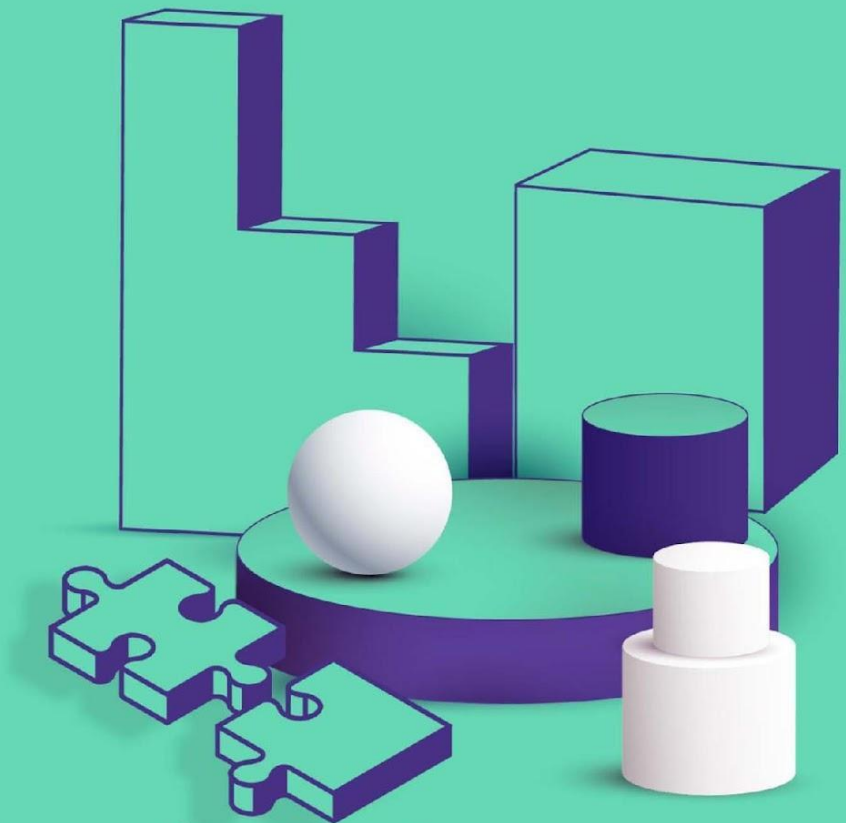
Co-funded by
the European Union

DIMENSION 3
PRINTED PUZZLES FOR
NEW THERAPEUTIC OPPORTUNITIES

PROJECT NUMBER:2021-1-ES01-KA220-ADU-000035313

Methodology of 3D printed puzzles applied to physical/psychological wellbeing



PARTNERS

aspaym castilla y león · CETEM · CEIPES · idec · ROSTO SOLIDÁRIO

CREDITS AND DISCLAIMER

This document is the collective effort of many individuals and partner organisations working on behalf of the project "D3PO - Dimension 3 Printed puzzles for new therapeutic Opportunities", project number: 2021-1-ES01-KA220-ADU-000035313. Every attempt has been made to ensure that the contained information is true and accurate.

Every reader and user are expressly advised to use the content and information of this document on their own responsibility.

The Erasmus+ Programme support to produce this publication does not constitute an endorsement of the contents, which reflects only the views of the authors.

Project Reference

"D3PO - Dimension 3 Printed puzzles for new therapeutic Opportunities"

2021-1-ES01-KA220-ADU-000035313

Erasmus + Programme of the European Union

Lead Partner

FUNDACIÓN ASPAYM CASTILLA Y LEÓN [Spain]

Partners (Alphabetic Order)

CENTRO INTERNAZIONALE PER LA PROMOZIONE DELL'EDUCAZIONE E LO SVILUPPO ASSOCIAZIONE [ITALY]

CENTRO TECNOLÓGICO DEL MUEBLE Y LA MADERA DE LA REGIÓN DE MURCIA (SPAIN)

IDEC (GREECE)

ROSTO SOLIDÁRIO - ASSOCIAÇÃO DE DESENVOLVIMENTO SOCIAL E HUMANO [PORTUGAL]

Authors (Alphabetic Order)

José Jiménez – ASPAYM

Orestis Ntagiantas – IDEC

Raquel Ortega– CETEM

Patrícia Ribeiro – ROSTO SOLIDÁRIO

Jaqueline Rinaldi - CEIPES

Table of Contents

1. Why this project?

"In every real man, a child is hidden that wants to play." - Friedrich Nietzsche

D3PO - Dimension 3 Printed puzzles for new therapeutic Opportunities - is a project supported by the European Commission through the Erasmus+ programme, Key Action 2 – Cooperation partnerships in adult education.

D3PO is an inclusive learning project based on playable mechanics through 3D printable puzzles. The idea was born as a result of the increasing popularity of escape rooms in recent years and its potential to promote the development of soft skills in the participants. However, these activities have been hampered due to the COVID-19 pandemic.

Our main goal is to use traditional cognitive development mechanics (puzzles) with a modern narrative-based approach (similar to escape rooms), which can be distributed to the general public in an economical and safe way (3D printing) and that allow the acquisition of competences such as teamwork, creativity or lateral thinking, extremely useful in the work environment, while promoting inclusivity, tolerance and the value of the individual as a fundamental pillar of the society of the future.

Throughout this project, we developed a collection of puzzles that would cover a wide and diverse spectrum of action cases.

Given that puzzles have already had a long history in the therapeutic field as hand-eye coordination tools, we consider that their application at the individual level would have great therapeutic value (both physically and psychologically) but where they can stand out the most is in collaborative dynamics and teamwork.

We decided to use puzzles as a pedagogical and therapeutic tool, since they force you to work on body and mind at the same time.

Trying to accomplish the challenge the puzzle presents to you, you connect with the puzzle and at the same time, the puzzle makes you connect with the partners who are trying to solve it with you. Indeed, they help you develop your inner self and the bonds with the people near you as they are a key tool for socialisation.

We additionally wanted to offer the possibility to raise awareness on the topic we select for each puzzle. We considered that puzzles could be a great tool to meditate on these critical topics since the idea for the puzzles is to allow our target groups to spend their time exploring how and why the puzzle was created.

The usage of puzzles can also be valuable for therapeutic usage in the field of physical rehabilitation, especially after suffering a stroke. People who have survived this illness usually experience certain physical sequels and it is critical to act and proceed to rehabilitation as soon as possible in order to try to recover as much mobility and capacities as possible.

The decision of using 3D printing is due to its versatility to create newly adapted and custom tools, as well as its capacity to easily test prototypes, share and replicate the final outputs with the members of the consortium and anyone interested in the project.

The main goal of D3PO is to study and offer a methodology to help heal the body using the mind and help the mind using the body.

Our specific objectives are:

- To study and offer a methodology to help heal the body using the mind and help the mind using the body.
- To design innovative practices in the field of adult education by developing a methodology that will allow the acquisition of key competencies for the labour market.
- To improve the quality of life of our target group using non-formal education methodologies.

2. The partners

2.1. Fundación ASPAYM Castilla y León

https://www.aspaymcyl.org/

The ASPAYM Castilla y León Foundation began operating in 2004, twelve years after ASPAYM was founded in the region of Castilla y León, Spain.

Its main objectives are to promote autonomy, equal rights and opportunities and improve the quality of life of people with physical disabilities, allowing them a meaningful integration into society. In addition, ASPAYM CyL seeks to be a leading association, providing its target users with the tools to achieve that mission. This goal is achieved through the quality of its programs and activities, research, and the appropriate use of new technologies.

ASPAYM CyL develops a multitude of activities (advocacy, non-formal education, employment), as well as years of experience and multiple awards. Also, the awareness project "Ponte en mis zapatos" (Put yourself in my shoes) is developed, whose main objective is the standardisation of disability in schools, community centres, youth organisations, etc. In recent years, the organisation has been committed to the use of gamification as a methodology in non-formal education activities. In this sense, ASPAYM CyL has developed board games, video games, escape rooms and manuals based on this technique, always from an inclusive perspective to ensure equal access of people with disabilities to all available resources.

In addition, within ASPAYM we have a project called JAVACOYA, which was born with the pretension of providing a personalised service to our clients and overcoming the daily challenges set by the market. In addition, it offers a wide range of resources, all of them oriented to optimise and profit, with complete adaptation to your needs, such as accessible website design, web updating or development of custom software.

2.2. CEIPES - Centro Internazionale per la Promozione dell'Educazione e lo Sviluppo

https://ceipes.org/

CEIPES – International Centre for the Promotion of Education and Development is a non-profit organisation founded in 2007 and based in Palermo, Italy.

It leads a Network of more than 8 European and extra European associations focused on Education, Training and Social Development.

CEIPES has expertise on Education, Transfer of innovation and Project management in different European programmes tackling the Education and the capacity building of different target groups, from young people to adults, from women to unemployed, migrants and disadvantaged groups. It also promotes lifelong learning, vocational training and entrepreneurship with the aim of enhancing opportunities for youth and adults to improve and acquire competences and therefore boost their employability and inclusion.

CEIPES has several links with public and private local and international stakeholders that can contribute to the achievement of project results in terms of dissemination, exploitation and sustainability of them.

CEIPES can count on experienced staff composed of professionals with different competences and fields such as psychology, communication, training, international cooperation, social and cultural mediation, social assistance, ICT, digital manufacturing and law.

2.3. CETEM - Centro Tecnológico del Mueble y la Madera de la Región de Murcia

http://cetem.es

The Technical Research and Training Centre of Furniture and Wood of the Region of Murcia (CETEM) is a private and non-profit association based in the municipality of Yecla, where the most important furniture cluster in Spain is concentrated. The origin of CETEM dates back to 1995 thanks to the initiative of private companies with the support of the regional government, the Spanish Ministry of Industry and the European Union.

CETEM mission is oriented to improve, foster the continuous improvement, and transfer any type of innovation to companies, primarily SMEs, while actively contributing to their socioeconomic development through consultancy services, R&D activities, and training tailored to the needs of the industry and society.

The vision of CETEM is to be an international Centre of Excellence as a knowledge and technology provider, a pioneer in furniture-related and sector-transversal technological knowledge, and to be composed of a highly qualified and motivated technical team that communicates a high level of satisfaction to its associates and collaborators with the necessary strategic alliances with organisations to further its mission.

CETEM is formed by 39 professionals working in different areas of expertise: Product Engineering, Materials Science, Electronics & Domotics, Process technology and Innovation management. As a Training Centre, CETEM manages over 30 VET programmes per year, covering a wide range of topics such as 3D design and printing, technology transfer, intellectual property rights, eco-design, Green Public Procurement, Industry 4.0, marketing, etc.

CETEM offers both face-to-face, online, and blended programmes managed through the learning platform Elernia (www.elernia.cetem.es), where learners can browse the training catalogue and even participate in online courses.

CETEM aims to be an economically, socially, and environmentally sustainable technology centre, approaching each initiative from a quadruple perspective:

- **Economic:** to generate innovation among companies from the furniture and other industrial sectors through cooperation, creativity, research, and learning.
- **Social:** improving people's quality of life and tackling unemployment, the skills gap or new training needs from an inclusive and diverse perspective without leaving anyone behind.
- **Environmental:** strong commitment to sustainability to respond to a new competitive imperative and drive sustainable value in the green and digital age.
- **Digital:** Boosting cooperation and experimentation with virtual and blended learning opportunities, through the eLernia platform and other collaborative digital tools.

2.4. IDEC

www.idec.gr

IDEC is a training consulting company located in Piraeus, Greece. Its activities consist of training, management consulting, quality assurance, evaluation and development of ICT solutions for both private and public sector.

IDEC has been active the last 20 years in the field of EU projects.

It has long experience in European policies regarding lifelong learning and in particular EQF, ECVET, Europass, EQAVET, validation of non-formal and informal learning, work based learning & apprenticeship schemes and in national reforms of education and training systems.

Through its Training Centre, IDEC organises national and transnational training sessions on a wide range of topics and of different types:

- In-service training courses for staff of education and training organisations across Europe, funded by the Erasmus+ programme of the European Commission.
- E-learning courses on vocational subjects or on key skills acquisition.
- Training courses complementary to our consulting activities e.g. staff training during the preparation for ISO 9001 certification

All our training courses have been designed in units of learning outcomes and have been assigned ECVET credit points.

In all our training courses, we use a constructivist learning approach. Our learners are invited to bring their experiences and case studies in the classroom, and we are working on real situations and problems. We use different learning methodologies, that require the active participation of the learners, so that they take responsibility and ownership of their learning:

- Brainstorming
- Role play games
- Projects
- Social learning
- Workshops

2.5. ROSTO SOLIDÁRIO - Associação de Desenvolvimento Social e Humano

ROSTO SOLIDÁRIO

www.rostosolidario.pt

RS work aims to foster global citizenship and solidarity by enhancing local communities' human and social development.

RS core principles are civic participation, social integration, solidarity, networking and partnership. The organisation's scope of work includes four main areas: International Development Cooperation, Global Citizenship Education, Volunteering and Family-based Social Support. Gender Equity, Human Rights and Social Inclusion are addressed as cross-cutting issues in all programs implemented. Also, Rosto Solidário takes Non Formal Education approaches to foster lifelong learning opportunities following Global Citizenship Framework.

RS legal status of public utility as an NGO has been recognized by the Ministry of Foreign Affairs in 2008. As a Portuguese NGOD Platform member it is represented both in the Working Group on Development Education and in the Working Group on Ethics. RS is an accredited hosting and sending organisation for European Voluntary Service projects since 2011.

At the local level, RS is a member of Rede Social do concelho de Santa Maria da Feira (local network of 115 organisations providing social services - following National Action Plan for Inclusion guidelines). Within this network, RS has been awarded four times with a recognition of its work in fostering volunteering work and supporting local communities' development.

Global Citizenship Education it's a core area at Rosto Solidário as we seek social transformation by raising critical awareness of the existing inequalities, promoting civic participation and intercultural dialogue as well as fostering solidarity and action towards common good and social change.

Regarding adult education at the local level, RS promotes local volunteering and has experience with adults with fewer opportunities. RS has partnerships with several institutions and has a social service office to support local communities, in particular those in vulnerable conditions.

3. Puzzles as a pedagogical and therapeutical tool

Body and mind are both intertwined. Their connection is rooted so deeply that one cannot healthily coexist without the other. When the body suffers, the mind suffers; and when the mind experiences an illness, the body may also receive the consequences.

Nowadays, there are many reasons that can provoke mind suffering, not only illnesses (like certain congenital diseases or the effects of a stroke). Some others and equally relevant are caused by social exclusion, discrimination, sexism, racism. Since both, mind and body, share such a unique bond, an effective tool to address any of both issues should require work on both at the same time.

Puzzles and riddles accompany us during our entire life. During our childhood, they teach us how to think outside the box; and when we grow, we are forced to substitute the Rubik cube for the balance of payment, a true puzzle where we need to control our debts.

They are also part of our lives when we need rehabilitation. Most specialised centres use them to help our brain recover control of our body. However, the importance of these geniuses are presented by the two following key factors:

- They are a key tool for socialisation.

- They challenge us to develop our inner selves.

In recent years, escape rooms and puzzle-solving have gained popularity among young people and also in working environments as a team engaging experience to reinforce bonds, teamwork and develop individual skills. They are indeed a narrative and a therapeutic tool. This is especially helpful for people with difficulties to feel integrated into a certain team, especially in the case of people with fewer opportunities (impairment, immigration, refugees, social hindrances and economic barriers). The puzzles should additionally be helpful in the context of physical and neurological rehabilitation since they require the usage of the brain with coordination.

3.1. Areas of intervention

Solving simple puzzles can help to “rewire” the brain, and it may even help to repair damage caused by traumatic injuries. By working with puzzles, people can activate long-dormant parts of their brains.[1]

People are typically capable of handling various types of puzzles at specified ages. This means that adults should pay more attention to the complexity of puzzles. Puzzles perform wonders to our

[1] https://bigthink.com/neuropsych/brain-puzzles/?fbclid=IwAR2S2Xq3Wzq4A6mWpFTSP904lmNTwFMUrFR1xOefjzZ8-qXnMRkGvOOshlw

human minds and children, adults, or the seniors can significantly benefit from improved memory, brain chemistry, disposition, and creativity. [2]

In that way, puzzles are beneficial for every age, seeing that the young possess highly malleable minds while adults and seniors are more vulnerable to recollection difficulties.

That's why, puzzles can be use in several domains and intervention areas, namely:

3.1.1. Children Development

Playing with puzzles has significant impacts on a child's physical skills, developing fine motor skills through the coordination of small muscles. Through grasping pieces and matching pieces together, children also improve their spatial awareness and hand-eye coordination. There are also lots of cognitive benefits that playing with puzzles can have for children, namely, to promote the development of their reasoning and decision-making skills. Playing and solving puzzles encourage children to use their reasoning skills by weighing up which piece to put where and working out which piece to use next to help them get one step closer to completing their puzzle. The use of puzzles also helps children to become more confident and determined by seeing their persistence pay off, giving them a sense of achievement once the puzzle is complete. Puzzles not only encourage independent learning and decision making but can also be used to promote social interaction.[3]

In that way, puzzles can help children to develop several different skills that are important for learning subjects such as reading, writing, and maths.

We can conclude that puzzles can help children to:

- Develop fine motor skills and improve their hand-eye coordination.
- Improve the ability to concentrate and stay focused on one task at a time.
- Feed the brain, especially their mathematical thinking.
- Enhance their visual perception and eye for details.
- Teach social skills, empathy, and communication skills when playing with others.

3.1.2. Active Ageing

Often puzzling demands multiple visuospatial cognitive abilities and is a potential protective factor for cognitive ageing.

Studies also suggest that playing puzzles can improve visual-spatial processing, problem-solving skills, and short-term memory, particularly in older adults. In addition, they have been shown to slow down cognitive decline as we age, potentially reducing the risk of developing dementia. [4]

[2] https://www.dumblittleman.com/5-benefits-puzzles-solving-adult/?fbclid=IwAR1c-bO67HuJYW4Fd1C7g9BRKrsTl3XUo452EwWngesp2M1pboGmkjeiz1o

[3] https://www.orchardtoys.com/blog/the-benefits-of-jigsaw-puzzles-for-children_97026054.htm

[4] https://www.forbes.com/sites/nomanazish/2023/04/30/cant-meditate-heres-why-you-should-try-jigsaw-puzzles-instead/?sh=73487e8e3f1b

Also, some research found that older adults who regularly take part in word and number puzzles have sharper brains. The more often they played puzzles, the better their brain function. Another finding is that doing crossword puzzles could reduce the onset of dementia by two and a half years.

That's why elderly people can benefit so much by playing and solving puzzles on a regular basis and as part of their daily routine.

3.1.3. Mental Health

Puzzles can be a great therapy tool, helping to reduce stress and anxiety, improve mood, and provide a sense of relaxation. Puzzles can also be a great way to practise mindfulness, as they require you to focus on the present moment and let go of distractions. Literature suggests that in our multi-tasking current way of life, it helps to focus our mind on a single task, which can help to reduce stress and anxiety and provide a source of relaxation.[5]

In fact, puzzling can contribute to decrease the levels of anxiety: "*Solving jigsaw puzzles for just 30 minutes a day for eight weeks can lead to a significant decrease in anxiety levels in adults with generalized anxiety disorder*," (Porter, 2023).[6]

In that way, solving puzzles can be a great mindfulness exercise that helps redirect a person's attention to the present moment. By fully immersing in the task at hand, the brain enters a state of flow, like when we are meditating.

Another important aspect is that the act of completing a puzzle, no matter what kind, creates a positive reinforcement cycle of finding solutions. For instance, evidence suggests that finding puzzle pieces or doing any type of puzzles are small wins that can help release dopamine in your brain resulting in a positive mood (Bergland, 2011).[7]

After solving a puzzle, the brain produces a neurotransmitter called dopamine which acts as a messenger between nerve cells and is responsible for regulating moods and emotions. An increase in the dopamine levels in the body naturally decreases the production of cortisol, which is a hormone that acts as an alarm when the body is under stress.

Puzzling can serve to cope with stressors by regulating distressing emotions (Hutchinson et al., 2003, cit. Fissler et al., 2018) and can depict a "breather" from stress (Lazarus et al., 1980, cit. Fissler et al., 2018), which may result from its focused attentional demands that enables a psychological time out from stressors. Puzzling can also serve as a mood enhancement through fun, flow, and mastery experiences.[8]

Finally, the sense of accomplishment, distraction from negative thoughts and the relaxing effect of doing a puzzle can help people who struggle with depression.

---

[5] https://www.med.unc.edu/phyrehab/wp-content/uploads/sites/549/2020/04/4.3.2020-Wellness-v2.pdf

[6] https://www.forbes.com/sites/nomanazish/2023/04/30/cant-meditate-heres-why-you-should-try-jigsaw-puzzles-instead/?sh=73487e8e3f1b

[7] https://www.psychologytoday.com/intl/blog/the-athletes-way/201112/the-neuroscience-perseverance

[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6174231/

3.1.4. As part of therapy for Neurological Impairments

For many people puzzles can be quite demanding. Puzzles offer great exercise for strengthening and refining skills in three main areas: Cognitive, Physical and Emotional.[9]

Puzzles, in various forms, can be valuable tools in the rehabilitation process for individuals with neurological impairments. Engaging in such activities can help retrain and enhance cognitive functions that may have been compromised due to brain damage. Regardless of the stage of the disease, puzzles have the potential to alleviate some symptoms while bestowing a sense of control and soothing comfort upon the patients. Beyond memory, the puzzles contribute to improved mental speed, thought processes, and cognitive functioning, aiming to mitigate the decline often associated with these conditions.

Overall, puzzles offer an enjoyable and effective way to support and stimulate the brain for those with neurological impairment. They provide mental exercise and help improve cognitive skills like problem-solving, memory, and attention. Solving puzzles also enhances fine motor skills, which can be beneficial for individuals with conditions like Parkinson's disease or brain injuries.

Puzzles involving colours and shapes can improve visual perception abilities, while the need for concentration and focus during puzzle-solving can be a great exercise for individuals struggling with these skills.[10]

For those with conditions such as Attention Deficit and Hyperactivity Disorder (ADHD), puzzles can help improve focus and attention skills and encourage calmness. Puzzles can be a supportive therapeutic intervention for some people with ADHD, especially in the form of “play therapy”.[11]

"Many people with ADHD experience disorganized thinking. Working on a jigsaw puzzle can help them slow down and focus on one task at hand (…) While someone with ADHD might not be able to focus on a puzzle for a long period, engaging with a puzzle for a while can help them think more clearly and even tap into their emotions which then are helpful to process via other forms of therapy”.[12]

Puzzles are also a commonly reported favourite activity for people with autism because they allow to assemble irregular tiles into a complete picture, are tactile, repetitive, and have a single solution. Also, puzzles often have a clear objective and concrete rules. On the other hand, paying and solving puzzles is an activity that can be done individually or side-by-side without requiring extended social interaction. Puzzles also offer a tangible cause-and-effect between the person’s activity and the final goal of the puzzle. For people who struggle with abstraction, physically completing a picture piece by piece makes sense.

---

[9] https://www.cheshirefitnesszone.com/occupational-therapy-puzzles/?fbclid=IwAR13r1xX0vvP12q91yWVu9ndOSqBlYHpptJBJYryl67XLwOu_BcDgRa5Cz8

[10] https://www.neuro-connect.org/puzzles

[11] https://www.printsinpieces.com/blogs/chat/puzzles-and-wellbeing-are-jigsaws-good-for-mental-health

[12] https://www.forbes.com/sites/nomanazish/2023/04/30/cant-meditate-heres-why-you-should-try-jigsaw-puzzles-instead/?sh=1afc24973f1b

Puzzles are, by nature, a repetitive task that leads to a greater outcome. Such structured play activities can benefit the people doing them. Repetition lends a sense of order and predictability for the person, yielding a sense of calmness and control. Some adults with autism have also affirmed that engaging in this kind of harmless repetitive behaviour can be a form of self-regulation and a healthy outlet for stress and anxiety.[13]

3.2. Skills development and Benefits of playing puzzles

For a long time now, researchers have continually made efforts geared towards the determination of the benefits of fun puzzles to solve, especially to the human mind. The importance of puzzles can be directly linked to how complex and demanding they are.[14]

"(…) puzzling may demand multiple cognitive abilities including visual perception (e.g., recognizing objects, patterns, and orientation of lines), constructional praxis (e.g., integrating visual and motor information to assemble pieces), mental rotation (e.g., mentally rotating piece's orientation to fit them to other pieces), cognitive speed and visual scanning (e.g., sorting puzzle pieces), cognitive flexibility (e.g., switching attention between different strategies, between different puzzle pieces, and between puzzle shape, image, and color), perceptual reasoning (e.g., integrating different perceptual information to develop strategies and plans how to solve the puzzle), and working and episodic memory (e.g., keeping the association between spatial location and visual patterns/images of puzzle pieces in working memory and long-term memory) (Fissler et al, 2018)."[15]

3.2.1. Motor & sensorial skills

Some puzzles require fine motor coordination and controlled use of the upper extremities. Depending on the type of puzzle, individuals may need to manipulate pieces, which can contribute to the development or improvement of fine motor skills. This is particularly beneficial for those who have experienced motor impairments.

There are lots of fingers and hand movements when playing with puzzles. Also, some of the smaller pieces require a delicate grip when being manipulated.

In this way, playing puzzles can improve/develop for instance:

- Fine motor skills: Grasping and fiddling with puzzle pieces activates the smaller muscles in a person's hands and wrists.

[13] https://diversityintoys.com/why-children-with-autism-love-jigsaw-puzzles/

[14] https://www.dumblittleman.com/5-benefits-puzzles-solving-adult/?fbclid=IwAR1c-bO67HuJYW4Fd1C7g9BRKrsTl3XUo452EwWngesp2M1pboGmkjeiz1o

[15] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6174231/

- Hand-eye coordination: Selecting and placing the individual pieces improves a person's hand-eye coordination.
- Visual processing: To assemble the puzzles, we need to put all these different pieces into a bigger picture. Each puzzle-piece is part of a bigger picture, and this teaches us to see the big picture, while still having an eye for the detail. A person's visual perception is trained in this way. Also, regularly performing an exercise helps us improve spatial orientation.

3.2.2. Cognitive Skills

Working out puzzles reinforces the existing connections between our brain cells and boosts the generation of new ones. Those effects greatly enhance our mental speed and thought process.

Mind puzzles for adults demand the ability to recognize the different parts plus the whole picture of the problem. The task of fitting pieces together engages both the logical and creative sides of the brain, promoting holistic cognitive function. In that way, assembling puzzles can be considered a complete brain exercise, as it activates both the left and right halves of the brain. The right side is in charge of creativity, emotions and instinctive thinking, while the left is the logical, objective and methodical side. When putting together puzzles, both sides need to communicate and work together, which increases cognitive functions. The occipital part / cerebellum is the area where the brain connects colours and shapes, which is also activated.

Exercising the mind helps prevent cognitive decline. In that way, puzzles teach and strengthen visual processing, perception, organisation, sequencing, concentration, and more. Puzzles, especially those involving problem-solving, memory, and attention, provide cognitive stimulation. In that way, puzzling can promote some cognitive skills like:

- Focus: The act of concentrating on puzzle pieces can provide a calming activity, helping to reduce restlessness and anxiety that might accompany these conditions. When solving a puzzle, especially if the parts are very similar, it is crucial that you pay attention to detail. You need to train your eyes to find small differences in colours or shapes to help you complete the puzzle.
- Problem solving: Puzzles are games of problem-solving. Puzzles often require individuals to adapt to different challenges and learn new strategies. This adaptive learning process can be transferable to real-life situations, helping individuals better cope with the demands of daily living. To solve the puzzles, we use different approaches to solve the problem, as it is trial and error testing. We also learn the value of formulating theories, testing hypotheses, and changing perspective when something doesn't go as planned. Through formulation of theories and testing these hypotheses, we gain the benefits of combining creativity with an

empirical examination. This type of imagination often leads to innovative, precognitive and efficient problem-solving skills in various fields.[16]

- Memory: A person's working memory is critically important for functioning in daily life. Older people and those who have Parkinson's disease, dementia, or who have had a stroke may experience a degradation of their working memory. For individuals grappling with memory-related conditions such as Dementia and Alzheimer's, the profound impact of puzzles on cognitive health is important, as they serve as potent tools, empowering patients to engage in activities that exercise memory, stimulate brain functions, and remarkably enhance short-term memory.

  If the puzzle is customised to the patient a remarkable transformation can occur. Each piece laid in place can promote the ability to focus, remember, and reconstruct. The act of fitting together the pieces become a journey of reconnection, a passage through the corridors of their history, and a rekindling of emotions long buried.

3.2.3. Intra and Interpersonal Skills

Solving puzzles can be a rewarding and enjoyable activity, contributing to a positive emotional state. It can also serve as a means of reducing stress and anxiety, promoting psychological well-being during the rehabilitation process. Completing a puzzle offers a tangible sense of achievement, boosting self-esteem and emotional well-being.

The satisfaction of finding and placing a puzzle piece releases dopamine, a neurotransmitter associated with pleasure and happiness. This neurotransmitter causes improved motoring skills, an increase in concentration power, optimism, confidence, and an enhanced recollection.

On the other hand, trying to accomplish the challenge the puzzle presents makes you connect with the partners who are trying to solve it with you. Indeed, they help you develop your inner self and the bonds with the people near you as they are a key tool for socialisation. The experience of reaching a goal by joint effort is important. In the process, we learn to decode other people's feelings, to be part of a team, and to rely on others for help and guidance. This not only promotes empathy and integrity but also verbal and non-verbal communication skills.

Also, some puzzles are designed for collaborative efforts. Engaging in group puzzle-solving activities can facilitate social interaction, fostering a sense of community and support among individuals and offers a chance for emotional bonding. The tactile engagement of piecing together a puzzle can act as a stabilising force. In this way, assembling a puzzle becomes a collaborative effort, enabling people to interact with those around them in a positive and engaging manner.

[16] https://www.dumblittleman.com/5-benefits-puzzles-solving-adult/?fbclid=IwAR1c-bO67HuJYW4Fd1C7g9BRKrsTl3XUo452EwWngesp2M1pboGmkjeiz1o

4. Methodology of 3D printed puzzles applied to physical/psychological wellbeing

4.1. Description of our puzzle collection

D3PO developed a collection of puzzles that cover a wide and diverse spectrum of action cases. The D3PO Project not only promotes sensory and cognitive engagement through puzzle manipulation, but also opens doors to new therapeutic perspectives. Customising puzzles to suit individual needs is an integral part of our mission to promote well-being through innovation.

We consider that the application of our puzzles at the individual level would have a great therapeutic value (both physically and psychologically), but where they can stand out the most is in collaborative dynamics and teamwork. We decided to use puzzles as a pedagogical and therapeutic tool, since they force you to work on body and mind at the same time.

Here are a summary of our puzzle's collection:

4.1.1. Arabian Nights Series - The Palace of Shahriar

The Arabian Nights is a popular collection of traditional mediaeval tales from the Middle East. The theme includes an oriental-themed design, as well as quizzes reminiscent of the most popular stories in the collection (for example, finding the magic lamp). We have considered its choice due to the centuries-old influence of Eastern culture in Spain during the Middle Ages.

This puzzle is focused on the general story of the Arabian Nights, where Sherezade is locked in a palace telling stories to the sultan Shahriar.

For it, it is needed (and so trained) hand-and eye coordination, social inclusion, screw-unscrew, basic maths, braille.

4.1.2. Arabian Nights Series - The Cave of Wonders

The theme will include a design inspired by Ali Baba's cave, as well as quizzes reminiscent of the most popular stories in the collection (for example, opening the mouth of a panther where you can find the magic lamp).

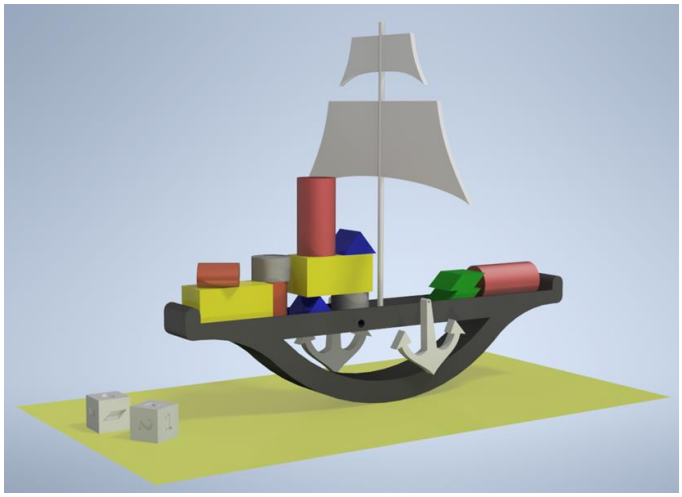
This puzzle is focused on the story of Ali Baba and the 40 thieves and its relation with the Aladdin story added later on to the collection of stories in the Arabian Nights.

For opening the mouth of the panther and getting the magic lamp, the user must train hand-eye coordination, memory and logic, by interacting with the elements that will find inside the cave.

4.1.3. The last voyage of 'Our Lady of Mercy'

In late 1804, a majestic frigate named 'Our Lady of Mercy' belonging to the kingdom of Spain, embarked on a voyage from Montevideo (Uruguay) to the Spanish coasts of Cadiz. Onboard, the ship carried a wealth of treasures, including gold, silver, vicuña cloth, cinchona, cocoa, and cinnamon. However, near the end of its perilous voyage, the English Navy appeared and the ship was blown up and quickly sank off Cape Santa Maria, in the Portuguese Algarve. Regrettably, the ship's precious cargo was lost, along with the lives of 23 women and children and 226 brave sailors on their way home after a long time overseas.

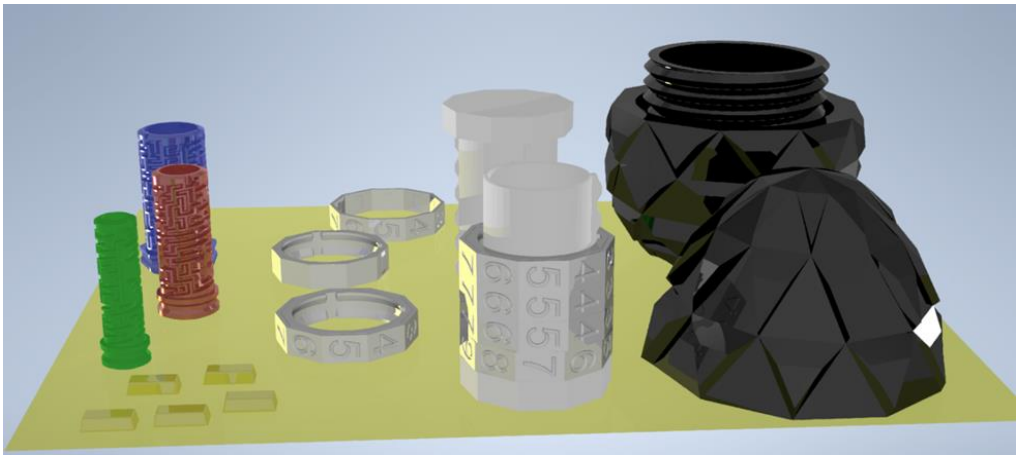
The objective of the game, which can be played either individually or in a group, is to place all the cargo on top of the ship and keep it in balance without capsizing. To do this, the dice will indicate the piece to place as well as the number of pieces to be placed each time.



4.1.4. The search of Moscow's gold

In the fall of 1936, a few months after the beginning of the Spanish Civil War, the government of the Second Republic, presided over by Francisco Largo Caballero and at the initiative of his Minister of Finance, Juan Negrín, ordered the transfer of 510 tons of gold, corresponding to 72.6% of the gold reserves of the Bank of Spain, from its deposit in Madrid to the Soviet Union.However, in 1938 the Soviet Union claimed that the gold stocks had already been exhausted. Was it true? More than eight decades later, speculation about whether the Soviets kept the money, or whether it was returned to Franco's Spain is still up in the air. The truth remains a mystery to this day.

The objective of the game, which can be played either individually or in a group, is to solve one by one all the puzzles and mazes to finally find the long-awaited gold of Moscow.



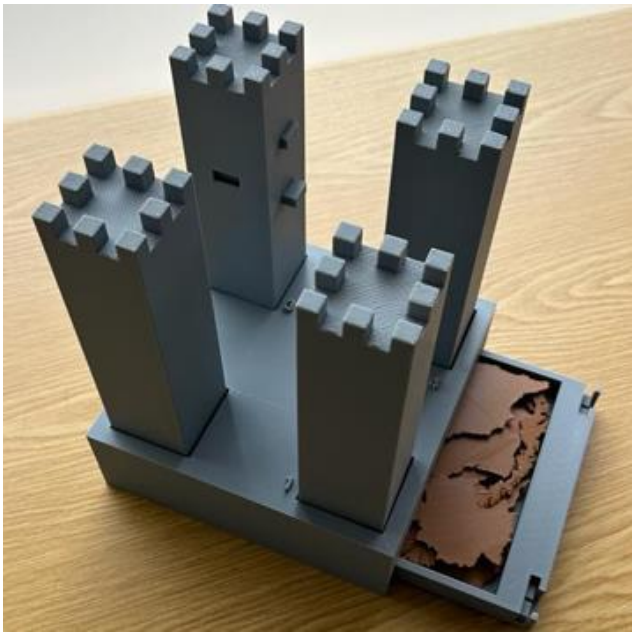
4.1.5. The castle of Europe

Castles mark a mediaeval era throughout Europe, associating the Middle Ages with wars and disputes over territories. Castles were symbols of feudalism and power, strategically positioned for population control and mercantile purposes.

In the contemporary world, Europe has been creating economic, political and social bonds defending a unity sometimes difficult to achieve.

The metaphor of this scape box is inspired by a castle as a symbol of security and community. In this sense, although each tower has different "mechanisms" representative of the differences between countries, the base of the castle represents the cohesion of the European territory. The puzzle represents a castle composed of 4 towers where each of these towers are a puzzle/riddle that needs to be solved in order to unlock a key for the final puzzle of Europe, which is hidden in a drawer at the base of the castle.

Through this game, focused on problem solving and strategy, participants can specially train the instructions comprehension, strategy, focus and problem solving (cognitive skills). Also, solving the puzzle can help to develop fine motor skills, hand-eye coordination, hand rotation and visual processing (motor and sensorial skills) and self-regulation, empathy and cooperation/teamwork (intrapersonal and interpersonal skills).



4.1.6. Fogaça

The Feast of Fogaceiras originated from a vow to the Martyr S. Sebastião, made by the people of the Land of Santa Maria, at a time when the region would have been plagued by an outbreak of plague that decimated part of the population. In exchange for protection, the people promised,

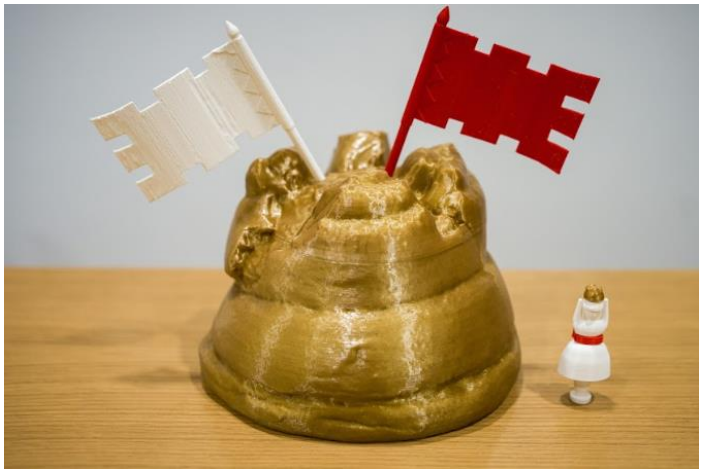
every January 20th, a procession and the offer of a sweet and thin bread, accustomed to be made for special occasions: the “fogaça”.

At the beginning of the fulfilment of the vow, it is referred to the existence of three “fogaças” made specifically for the ritual of devotion, which were taken in procession by three young maidens, from the Castle to the Mother Church, where they were blessed, cut and divided by the people present there, serving as a palliative against the evils of the world: hunger, plague and war.

As in the past, today the people of the municipality of Santa Maria da Feira, Portugal, have the opportunity to manifest the cult of S. Sebastião at a party, which is the “fogaça”, representing the figure of the Feira Castle, symbol of union and collective identity of this vast territory. Tradition dictates that, on the occasion of the Feast of the Fogaceiras, the inhabitants of Santa Maria da Feira send “fogaças” to their relatives and friends who are far away.

The objective of this game, which was specially developed to play in group, is to open 3 of the Fogaça’s tower and collect the parts of the “Fogaceira” doll. After catching all the parts, the goal is to open a trap door with the doll, where they can find the final piece of the doll: a little “Fogaça” to put in her head.

This game aims to stimulate motor, sensorial, cognitive, intrapersonal, and interpersonal skills in the participants. Through this game, focused on problem solving and strategy, participants will be able to enhance their visual processing, thus training their focus and stimulating their capacity for mental agility. Participants can specially train the instructions comprehension, strategy, focus and problem solving (cognitive skills); fine motor skills, hand-eye coordination, hand rotation and visual processing (motor and sensorial skills) and self-regulation and cooperation/teamwork (intrapersonal and interpersonal skills).



4.1.7. The Exit Within

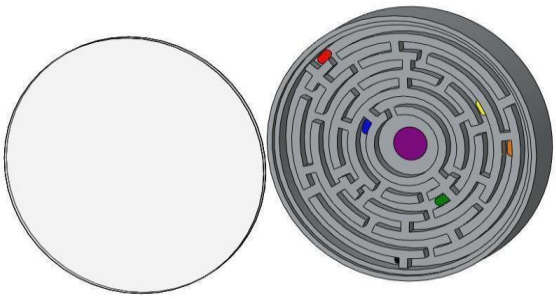
"The Exit Within" is a physical puzzle designed to symbolize the journey of mental health recovery. The puzzle incorporates a short story about John, a young person with mental health issues, who dreams of being trapped inside the maze. This narrative adds depth and context to the puzzle's theme.

The puzzle consists of a maze with a sphere inside it, featuring five colored dots (red, blue, green, yellow, orange) on its floor. The player's objective is to guide the sphere to land on each of the colored spots, triggering corresponding mental health recovery steps displayed in a virtual environment accessible through a QR code.For each color that the player reaches with the sphere, he/she is presented with a set of mental recovery steps that may contain both true and false information.

The journey of the sphere inside the maze symbolizes the fact that when struggling with mental health, there is not a defined exit, but rather a series of steps that you have to take to recover.

This puzzle engage players in critical thinking and decision-making regarding mental health recovery steps; encourage players to discern accurate mental health information from misinformation and foster understanding and empathy for individuals facing mental health challenges.

The puzzle is designed to be used as a tool for promoting mental health awareness and understanding. Its purpose is to engage participants in a symbolic journey of mental health recovery, fostering empathy, and critical thinking regarding mental health issue. It also aims to help people with learning difficulties by stimulating certain skills such as hand-eye coordination/rotation, visual processing, instruction comprehension, self-regulation and empathy.



4.1.8. Flying the Flag

" The "Flying the Flag Cryptex" is a physical puzzle designed around the concept of LGBTQI+ pride and flag symbolism. It consists of a cryptex with six colored rings (red, orange, yellow, green, blue, purple), each containing 10 digits from 0 to 9. These rings are arranged on a cylinder, seated on a round base, and are secured with a round lid on top.he process of solving riddles and aligning the cryptex's code enhances participants' problem-solving skills. It encourages logical thinking and the ability to work through challenges, which can be beneficial for individuals with learning difficulties as they develop and strengthen these skills.

Also, it is meant to increase awareness and understanding of LGBTQI+ issues and individuals. By immersing participants in a narrative centered around the LGBTQI+ community's quest for their flag, the puzzle fosters empathy and encourages players to learn about the challenges faced by this community. This increased awareness can lead to more inclusive and accepting attitudes in society.

Facilitators can adapt the puzzle by creating their own custom quizzes or riddles. This feature allows the puzzle to be tailored to the specific needs and abilities of participants, making it a versatile tool for educators and caregivers working with diverse groups of learners.

In this way, The "Flying the Flag" Cryptex puzzle serves a dual purpose of raising awareness about LGBTQI+ issues and providing mental stimulation and learning opportunities, particularly for individuals with learning difficulties.

4.1.9. Colapesce

Colapesce puzzle consists of several pieces that must be put together. The legend will be performed and set in Sicily, the island and region of southern Italy. The island and its triangle shape will be the central piece of the puzzle. Then there will be the columns that will have to be put together to support Sicily. In one of the columns, it will be Cola Pesce himself who will hold up Sicily. Each piece will have to be placed in the assigned spot. To hold up the island. In the upper surface of the island (triangle) will be placed, mountains, rivers, cities, and the volcano Etna. The objective will be not to slide all the pieces that make up the island when the island has to be supported by the columns.

The use of puzzles can be therapeutic for people with special learning disorders. The special benefits of this puzzle are development of teamwork, problem solving, orientation and logical application.

4.1.10. Around the World in 80 Days

Around the World in Eighty Days is an adventure novel by French author Jules Verne, first published in 1872. In this story the English gentleman Phileas Fogg, from London, and his new French helper Jean Passepartout attempt to circumnavigate the globe in 80 days, in order to win the £20,000 bet made with the other members of the Reform Club.

The puzzle consists of several parts and it is necessary for the facilitator to prepare it in advance. In each phase there are components that are not 3D printed but must be downloaded (project website) and printed. In the file provided, you can read the instructions for placing the 2D material inside the 3D puzzles. The puzzles consist of 6 puzzles, each of which represents different stages that players have to solve through codes to find and unlock.

The animator must know all the solutions to the puzzles in order to supervise and suggest any wrong moves that could compromise the integrity of the puzzle. In fact, it is necessary to communicate to the participants that no piece of the puzzle should be forced.

4.2. Explaining the skills matrix and its usefulness

Within the framework of the D3PO project, the partnership developed a skills matrix that had a specific purpose in the context of using puzzles as therapeutic interventions or activities, in order to make it easier for partners to implement the puzzles in each of their chosen target groups.

The different cognitive, emotional and psychological abilities and skills that people can acquire or improve through participation in puzzle-based therapeutic activities are referred to as skills in therapeutic puzzles, which ultimately can help individuals tackle specific therapeutic difficulties and achieve goals.

The main goal of the D3PO skills matrix is to help therapists select the most appropriate puzzles and track how well individuals are developing certain targeted skills by harnessing the benefits of puzzle activities for therapeutic purposes. Encouraging feedback and acknowledging progress can

encourage individuals to carry out therapeutic puzzle exercises in the future. Additionally, the skills matrix can support patients and therapists so that they can visualize their progress during the therapeutic process, allowing them to evaluate their process and set more ambitious goals, inspiring them to continue with the therapy by giving them a sense of accomplishment.

In this way, D3PO puzzles can be integrated into a broader therapeutic program, and the skills matrix can help to track in detail the changes in the individual's skills and abilities as he or she participates in puzzle-based interventions. It is important to note that the choice of therapeutic puzzles and how they are incorporated into a therapeutic process depends on the specific goals and needs of the individual or group receiving therapy.

The skills assigned to the D3PO puzzles have been categorised into three groups:

1. **MOTOR & SENSORIAL SKILLS**

   - Fine motor skills: the coordination and control of small muscles, usually in the hands and fingers, that enable us to perform precise movements and tasks. These skills involve the coordination between the brain, muscles, and nervous system to manipulate objects with dexterity and accuracy.
   - Hand-eye coordination: the ability to synchronise the movements of the hands and fingers with the visual information received by the eyes. It involves the coordination between the visual system, which processes information from the eyes, and the motor system, which controls the movement of the hands and fingers.
   - Visual processing: the process of how the eyes and the brain work together to turn visual information into messages that the brain can perceive, interpret, process, and understand.
   - Hand rotation: rotation includes two types of movement needed for fine motor activities: simple rotation: turning or rolling an object 90 degrees or less with the fingers moving as a unit (i.e., unscrewing a toothpaste lid, or spinning a pencil to adjust when erasing or getting a pencil comfortable in the grip). Complex rotation: turning an object more than 90 degrees using isolated finger and thumb movements (i.e., turning a paperclip, or turning a pencil over to erase).
   - Tactile processing: the cognitive and neurological ability to perceive and interpret information through the sense of touch. It consists of the brain's ability to receive, analyze and integrate tactile stimuli from the skin and other sensory receptors throughout the body.

2. **COGNITIVE SKILLS**

- Focus: psychic process that is carried out by means of reasoning; it consists of voluntarily focusing all the attention of the mind on an objective, object or activity that you are carrying out or thinking of carrying out at that moment, leaving aside all the facts that may interfere with your attention.
- Problem solving: the ability to identify, analyse, and develop solutions to complex or unfamiliar problems. It involves employing critical thinking, logical reasoning, and creative strategies to overcome obstacles and achieve desired outcomes.
- Strategy: the ability to plan, organise, and execute a series of actions or steps in order to achieve a specific goal. It involves the use of higher-level thinking processes, such as problem-solving, critical thinking, and decision-making, to develop and implement effective approaches.
- Instruction comprehension: the ability to understand and interpret instructions or directions accurately. It involves comprehending the information provided, extracting the relevant details, and grasping the intended meaning and purpose behind the instructions.
- Information processing & association: the way the brain receives, organises, stores, and retrieves information, as well as the ability to link or associate different pieces of information together. These skills are essential for learning, memory, and higher-level cognitive functions.
- Memory: the brain's ability to encode, store, and retrieve information over time. It involves the processes by which information is acquired, retained, and later recalled or recognized when needed.

3. INTRA & INTERPERSONAL SKILLS

- Self-regulation: the ability to manage and control one's own thoughts, emotions, and behaviours in order to achieve desired outcomes and maintain positive relationships with others. It involves self-awareness, self-control, and the ability to adapt and regulate one's responses to different situations.
- Empathy: the ability to understand and share the feelings, perspectives, and experiences of others. It involves the capacity to put oneself in someone else's shoes, to imagine their emotions and thoughts, and to respond with care, compassion, and understanding.
- Cooperation & teamwork: the ability to collaborate and work effectively with others towards a common goal. They involve actively engaging with others, sharing

responsibilities, communicating effectively, and fostering a positive and productive team environment.

During the initial development phase of the puzzles, each of the partners evaluated on a scale of 1 to 3 ('1-Not really', '2-Works this skill', and '3-Really relevant skill') the level at which each of the puzzles addressed each of the identified skills. However, after the pilot phase, this rating was reviewed and re-evaluated by each of the partners in order to update it after the experience with the target groups.

	DEVELOPMENT OF SKILLS													
	MOTOR & SENSORIAL SKILLS					COGNITIVE SKILLS						INTRA & INTERPERSONAL SKILLS		
PUZZLE	Fine motor skills	Hand-eye coordination	Visual processing	Hand rotation	Tactile processing	Focus	Problem solving	Strategy	Instruction comprehension	Information processing & association	Memory	Self regulation	Empathy	Cooperation & teamwork
The Arabian nights and the palace of Shahriar	3	2,5	3	3	2	3	3	2,5	2	2,5	1,5	2	1	2,5
The cave o f wonders	2,5	2	3	2	2	3	3	2,5	3	3	2	2,5	1	2,5
Around the world in 80 days	2,5	3	3	2,5	2,5	2,5	3	2	2,5	3	1	1,5	1	2
Colapesce	2,5	3	3	2	2,5	2	3	1,5	1	2	1,5	2	1	3
The last voyage of Our Lady of Mercy	3	3	2	1,5	1,5	3	3	3	2	1,5	1	1,5	1	2,5
The search of Moscow's gold	2,5	2,5	3	3	2,5	3	2,5	2,5	1,5	2,5	1	2	1	2
The exit within	2	3	2	2,5	1	2	2	1	3	2	1	3	3	1
Flying the flag	2	1	2	2	1	3	3	1,5	3	3	1,5	2	3	1
The "fogaça" story	2	2	2	2	1	2,5	2,5	2	2,5	2	1	2	1	2
The Castle of Europe	2	2,5	2,5	2	1,5	2	2,5	2	3	2,5	1	1,5	2,5	2

4.3. Description of the target groups

4.3.1. Learning disorder

Specific Learning Disorders (SpLDs) represent a category of Neurodevelopmental Disorders that hinder the acquisition and utilisation of specific academic skills within areas such as reading, writing, mathematics, listening comprehension, and expressive language. These skills serve as foundational pillars for other scholastic learning.

The devised puzzles were tailored to be inclusive for the designated target group, employing activities that circumvent the need for intricate mathematical operations. Engagement with these puzzles is anticipated to yield numerous advantages for the identified target population.

These benefits encompass enhancement in concentration capabilities, cultivation of visual memory, stimulation of problem-solving proclivities, augmentation of spatial and geometric correlation proficiencies, nurturing of mathematical logic and categorization skills, refinement of motor aptitudes and spatial orientation, and absorption of knowledge concerning significant global edifices and locales – all facilitated through interactive gameplay.

Consequently, this approach is poised to elicit enjoyment during puzzle-solving endeavours. Through the act of resolving these puzzles and the framework underpinning this process, participants stand to accrue expanded knowledge, heightened self-awareness, and an improvement of their skill sets.

4.3.2. Neuropsychological rehabilitation & physical impairment.

The target group for neuropsychological rehabilitation includes adults who have experienced physical impairments stemming from various neurological conditions, such as strokes or cerebrovascular accidents, cerebral palsy, cranioencephalic traumas, degenerative diseases, and other pathologies affecting the nervous system. These individuals often exhibit a range of impairments across sensory, motor, cognitive, emotional, social, and communicative domains due to the impact of brain damage.

Stroke or Cerebrovascular Accidents (CVA): These incidents can lead to sudden disruption of blood flow to the brain, resulting in a variety of impairments depending on the affected area.

Cerebral Palsy: A group of disorders affecting movement, muscle tone, and coordination, often caused by damage to the developing brain.

Cranioencephalic Traumatisms: Injuries to the head and brain, which can result from accidents or falls, causing a range of neurological issues.

Degenerative Diseases: Conditions such as Alzheimer's, Parkinson's, or Huntington's disease, which progressively damage the nervous system over time.

Individuals within this target group may experience challenges in performing daily activities, maintaining social connections, and managing emotional well-being. Neuropsychological

rehabilitation aims to address these challenges through targeted interventions that promote recovery and adaptation.

While puzzles can be beneficial, it's essential for rehabilitation programs to be personalised and comprehensive, addressing the specific needs and goals of each individual within the target group. Rehabilitation should involve a multidisciplinary approach, including neuropsychologists, physical therapists, occupational therapists, and other healthcare professionals working collaboratively to maximise the effectiveness of the intervention.

4.3.3. Physical and neurological rehabilitation in cancer patients

The advances made in recent decades in both the diagnosis and treatment of cancer have managed to increase survival, but have also led to an increase in neurological complications in patients in the short, medium and long term.

These complications can be due both to the cancer itself and to the treatments. Many of these complications are potentially reversible, so early diagnosis and correct treatment can improve the neurological symptoms and quality of life of these patients.

In addition, oncology patients are more prone to strokes due to specific factors associated with cancer such as hypercoagulability and treatment, since both chemotherapy and radiotherapy can predispose to arterial or venous thrombosis.

- Neurological toxicity of chemotherapy and radiotherapy: Most cancer patients experience something that they describe as mental cloudiness or cognitive changes they might notice before, during, and after cancer treatment (short term memory loss, difficulty in maintaining attention, lack of concentration, reduced processing speed, difficulty in problem-solving, difficulty in learning and remembering new information, ...).

  This cloudiness or mental change is commonly referred to as ‘chemo brain’, and refers to cancer treatment-related cognitive impairment, cancer-related cognitive change, or post-chemotherapy cognitive impairment. These mental changes can make people unable to perform usual activities.

  For most people, these mental changes only last a short time. Others can have long-term or delayed mental changes. Even though its exact cause isn’t known, it can happen at any time when you have cancer.

  Cognitive rehabilitation may include activities to improve brain function such as learning how the brain works and ways to take in new information and performing new tasks to exercise your brain.

- Lymphedema: Lymphedema is a condition in which the lymph fluid does not drain properly. It may build up in the tissues and cause swelling. This can happen when part of the lymph

system is damaged or blocked, such as during surgery to remove lymph nodes, or radiation therapy.

Lymphedema can arise for almost all types of cancer, but its incidence is more common for breast cancer due to sentinel lymph node removal in the axilla and/or radiation therapy treatments. In this case, lymphedema is manifested by swelling in the arm and hand on the same side as the breast operation, which may be accompanied by stiffness, pain, loss of mobility and difficulty in mobilisation and flexibility of the arm, especially in the hand or wrist. Swelling usually develops slowly, over time. It may develop during treatment or it may start years after treatment.

4.3.4. Active ageing

Exercising the mind to keep it active is as important as maintaining physical fitness and strength in older age. To ensure that the brain works as best as it can, the mind needs to be challenged every day. Think of it as a mental workout that improves your problem-solving skills and attention span.

Brain games and puzzles provide an older person the opportunity to use their critical thinking and problem-solving skills, because our left brain is logical and works in a linear fashion, while our right brain is creative and intuitive.

In addition, they also increase the production of dopamine, a chemical that regulates mood, memory, and concentration. Dopamine is released with every success as we solve the puzzle. Games help to form new connections within your brain cells, improving your short-term memory. Puzzles take not only concentration but also dedication to a specific activity, whether it’s visual focus, mental focus, or both.

4.4. Description of the testing phase

4.4.1. Background

The pilot phase of the D3PO project took place from the spring up until november of 2023, with all the partners taking part and all the produced puzzles being tested.

During this period, each partner organised in its respective country a number of workshops, each of them led by a facilitator, in which one or more puzzles were tested with their assigned target groups.

The target groups that each partner, and hence its puzzles, was assigned were the following:

ASPAYM CYL	Neuropsychological rehabilitation & physical impairment.
CEIPES	Learning disorder
CETEM	+65 adults (Active aging) + cancer patients
IDEC	Mental/learning difficulties
ROSTO SOLIDARIO	+65 adults (Active aging)

In each workshop, the facilitator introduced participants into the D3PO project (overview, goals, target groups and benefits for them) and then presented the puzzle(s) that was/were tested.

This presentation comprised the demonstration of the puzzle's pieces along with its rules and goal.

The participants then got their hands on the puzzle and tried to solve it with the supervision of the facilitator.

By the end of the workshop, participants filled a standardised evaluation questionnaire regarding both the showcased puzzle(s) and the workshop itself, whether on printed paper or through Google form.

Each partner tested its own 2 puzzles, along with a number of puzzles of other partners.

During the pilot phase, each partner proceeded into fine tuning its puzzles according to the feedback that was received by participants, bringing them therefore in their today's final form.

Overall, participants had a very warm reception of the puzzles and they highlighted their potential, innovation and added value for their population group!

4.4.2. Overall Numbers

In total, the consortium organised 16 workshops and received a total number of 433 evaluation questionnaires!

	ASPAYM	CEIPES	CETEM	IDEC	ROSTO SOLIDARIO	TOTAL
Workshops	**5**	**2**	**3**	**4**	**6**	**16**
Questionnaires	**83**	**34**	**96**	**83**	**137**	**433**

Regarding the puzzles, we received the following number of questionnaires for each of them:

Puzzle	Number of questionnaires
Palace of Shahriar	20
The cave of wonders	21
Around the world in 80 days	12
Colapesce	66
The last voyage of Our Lady of Mercy	84
The search for Moscow's gold	46
The exit within	37
Flying the flag	42
The “Fogaça” story	91
The Castle of Europe	14

The difference in terms of numbers is related to the fact that some puzzles took more time to be printed and that put some constraints to be tested by more participants. However, each puzzle was tested at least by two partners on their target-groups.

4.4.3. Results per Puzzle

Here are the analytical results per puzzle that were received from the evaluation questionnaires, considering the answers of the participants:

Did you finish the puzzle?		
Puzzle	**Yes**	**No**
Palace of Shahriar	100%	0%
The cave of wonders	100%	0%
Around the world in 80 days	100%	0%
Colapesce	98%	2%
The last voyage of Our Lady of Mercy	90%	10%
The search for Moscow's gold	100%	0%
The exit within	95%	5%
Flying the flag	86%	14%
The “Fogaça” story	100%	0%
The Castle of Europe	100%	0%

More than a half of the 10 puzzles were successfully completed by all participants who played them. However, “Flying the Flag” was the hardest puzzle to be completed.

The appearance of the puzzle is good looking				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	25%	75%
The cave of wonders	0%	0%	5%	95%
Around the world in 80 days	0%	0%	75%	25%
Colapesce	0%	0%	53%	47%
The last voyage of Our Lady of Mercy	0%	0%	10%	90%

The search for Moscow's gold	0%	0%	33%	67%
The exit within	0%	5%	51%	43%
Flying the flag	0%	0%	55%	45%
The “Fogaça” story	1%	2%	34%	63%
The Castle of Europe	0%	0%	36%	64%

In terms of appearance, every puzzle of the D3PO collection was considered good looking by the participants, being the “Cave of Wonders” puzzle the most well appreciated.

The puzzle is easy to manipulate				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	5%	15%	50%	30%
The cave of wonders	0%	5%	48%	48%
Around the world in 80 days	0%	0%	67%	33%
Colapesce	5%	8%	64%	24%
The last voyage of Our Lady of Mercy	2%	10%	14%	74%
The search for Moscow's gold	0%	7%	54%	39%
The exit within	0%	8%	46%	46%
Flying the flag	0%	7%	40%	52%
The “Fogaça” story	1%	5%	46%	47%
The Castle of Europe	0%	0%	64%	36%

In terms of manipulation, it was important to understand if the puzzles were considered easy to manipulate by the participants. The results showed that the majority of puzzles were easy to manipulate; however some puzzles, namely The Palace of Shahriar, was considered more difficult

by the participants, maybe due to the tiny and complex pieces of this puzzle.

The size of the puzzle is correct				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	15%	85%
The cave of wonders	0%	5%	10%	86%
Around the world in 80 days	0%	0%	67%	33%
Colapesce	0%	0%	41%	59%
The last voyage of Our Lady of Mercy	0%	1%	25%	74%
The search for Moscow's gold	0%	4%	30%	65%
The exit within	0%	5%	49%	46%
Flying the flag	0%	0%	40%	60%
The “Fogaça” story	1%	11%	31%	57%
The Castle of Europe	0%	0%	36%	64%

In terms of the puzzle’s size, almost every participant agreed that all puzzles were well sized. However, “Fogaça puzzle” causes some doubts to some participants, because of the little size of the doll’s pieces.

The puzzle is resistant				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	15%	35%	50%
The cave of wonders	0%	0%	43%	57%

Around the world in 80 days	0%	0%	75%	25%
Colapesce	0%	0%	41%	59%
The last voyage of Our Lady of Mercy	0%	0%	13%	87%
The search for Moscow's gold	0%	0%	37%	63%
The exit within	0%	3%	49%	49%
Flying the flag	0%	7%	45%	48%
The “Fogaça” story	1%	20%	33%	47%
The Castle of Europe	0%	0%	64%	36%

Another question was related to the resistance of each puzzle. Once again, almost every puzzle was considered resistant by the participants who played them. The exceptions were “Palace of Shahriar” and “The Fogaça Story” because of the small pieces of some parts of the puzzles, which are more fragile.

I felt motivated to solve the puzzle				
	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	10%	90%
The cave of wonders	0%	0%	10%	90%
Around the world in 80 days	0%	0%	67%	33%
Colapesce	0%	0%	30%	70%
The last voyage of Our Lady of Mercy	0%	7%	15%	77%
The search for Moscow's gold	0%	2%	28%	70%
The exit within	0%	8%	57%	35%

Flying the flag	0%	5%	50%	45%
The “Fogaça” story	1%	0%	19%	80%
The Castle of Europe	0%	0%	64%	36%

In terms of motivation, all puzzles motivated the participants, which is a really good indicator, since the motivation to play is really important to engage persons into this process.

I felt engaged by the storytelling				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	25%	75%
The cave of wonders	0%	5%	29%	67%
Around the world in 80 days	0%	0%	58%	42%
Colapesce	3%	3%	44%	50%
The last voyage of Our Lady of Mercy	1%	1%	19%	79%
The search for Moscow's gold	0%	7%	33%	61%
The exit within	0%	11%	46%	43%
Flying the flag	0%	7%	40%	52%
The “Fogaça” story	1%	0%	23%	76%
The Castle of Europe	0%	0%	57%	43%

Also, an important aspect of D3PO’s puzzles was the storytelling that contextualised each puzzle. This aspect engages participants in the process of playing puzzles. The results showed that participants were engaged by the storytelling of each puzzle, which is really important.

I found the puzzle helpful				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	25%	75%
The cave of wonders	0%	0%	33%	67%
Around the world in 80 days	0%	0%	58%	42%
Colapesce	0%	0%	48%	52%
The last voyage of Our Lady of Mercy	0%	0%	24%	76%
The search for Moscow's gold	0%	4%	28%	67%
The exit within	0%	11%	54%	35%
Flying the flag	0%	10%	55%	36%
The “Fogaça” story	1%	0%	41%	58%
The Castle of Europe	0%	0%	14%	86%

One of the main goals of this project was to try to create tools that could be useful for participants to develop some skills. In this way, the answers to this question shows that almost every participant considered playing each puzzle useful for themselves.

In the same line, they also find that playing the puzzles could be an useful experience for other people, as we can see in the next table:

I think this puzzle is useful to others				
	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	15%	85%
The cave of wonders	0%	0%	24%	76%
Around the world in 80 days	0%	0%	50%	50%

Colapesce	0%	0%	6%	94%
The last voyage of Our Lady of Mercy	0%	0%	24%	76%
The search for Moscow's gold	0%	4%	17%	78%
The exit within	3%	11%	38%	49%
Flying the flag	0%	12%	33%	55%
The “Fogaça” story	1%	0%	29%	70%
The Castle of Europe	0%	0%	36%	64%

I would recommend this puzzle to others				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	0%	10%	90%
The cave of wonders	0%	0%	14%	86%
Around the world in 80 days	0%	0%	58%	42%
Colapesce	0%	6%	48%	45%
The last voyage of Our Lady of Mercy	0%	0%	12%	88%
The search for Moscow's gold	0%	4%	15%	80%
The exit within	3%	11%	43%	43%
Flying the flag	6%	9%	56%	28%
The “Fogaça” story	0%	1%	29%	70%
The Castle of Europe	0%	0%	36%	64%

In general, the participants would recommend playing the puzzles to other people. The only puzzles that caused more doubts were “Flying the Flag” and “The exit within”, maybe because the themes of the puzzles are more related to discrimination and mental health themes, that could be more difficult for some people.

The puzzle promotes teamwork				
Puzzle	Strongly disagree	Disagree	Agree	Strongly agree
Palace of Shahriar	0%	5%	10%	85%
The cave of wonders	0%	0%	14%	86%
Around the world in 80 days	0%	0%	50%	50%
Colapesce	0%	0%	38%	62%
The last voyage of Our Lady of Mercy	1%	0%	8%	90%
The search for Moscow's gold	0%	2%	49%	49%
The exit within	0%	8%	38%	54%
Flying the flag	0%	5%	5%	90%
The “Fogaça” story	1%	1%	25%	73%
The Castle of Europe	0%	0%	36%	64%

One of the major competences the puzzles should create in the participants is teamwork and the results shows that this was really an important issue for the participants, who find opportunities to play as a team in each puzzle of D3PO’s collection.

For me, the puzzle was				
	Too easy	Easy	Difficult	Too difficult
Palace of Shahriar	5%	35%	60%	0%
The cave of wonders	0%	43%	38%	19%

Around the world in 80 days	0%	67%	33%	0%
Colapesce	0%	70%	30%	0%
The last voyage of Our Lady of Mercy	10%	60%	29%	2%
The search for Moscow's gold	2%	46%	50%	2%
The exit within	8%	62%	24%	5%
Flying the flag	2%	60%	21%	17%
The “Fogaça” story	2%	77%	21%	0%
The Castle of Europe	0%	86%	14%	0%

Some puzzles were considered easier than others. We can highlight “The CAstle of Europe”, “Fogaça Story” and “Colapesce” as the easiest ones and “Palace of Shahriar” and “The search of Moscow’s Gold” as the ones considered more difficult by the participants.

4.4.4. Feedback of the Facilitators

Another important aspect in testing Phase was the perception that facilitators involved retained from their contact with the different target groups. In this way will be presented a summary of the feedback of each entity involved in the project, regarding the testing phase with its target-groups. Below there is a narrative wrap up of the pilot phase of each partner, as described by the partner’s facilitators:

ASPAYM

The pilot phase was carried out in collaboration with ICTIA: Specialized Rehabilitation Unit for Neurological Damage. Within the recovery and maintenance process, they work in the areas of occupational therapy, speech therapy, physiotherapy, health psychology and neuropsychology.
Before the testing sessions, the puzzle developers held meetings with the professionals who would act as facilitators in the testing to explain the details of the puzzles. They tested the puzzles to understand how they worked and to anticipate difficulties that could occur with the target users.
For the process to be optimal, it was decided to deploy a total of 4 sessions, plus 1 additional session for final tests.
The first session originally started with separate individual testing and had to be done on different days due to time and availability. After the first individual tests, the ICTIA professionals who

participated on the first day and the ASPAYM Castilla y León developers met to review those elements that could be done to facilitate the completion of the exercises. These changes included larger fonts in letters, highlighting colours with greater contrasts, elaboration of clue cards and some cables that allowed the padlocks to be manipulated more comfortably. The aforementioned changes were included in subsequent sessions.
Finally, it was closed with an activity carried out by 9 participants.
The second session allowed us to test several puzzles that, by extension, could not be tested during the first day since ICTIA recommended that these activities, to be truly useful for patients, must be self-contained in the same session. In this session, we focused on testing, especially The Search for Moscow Gold and Colapesce. It was carried out with 8 users plus an additional one who suffered from dementia and could only be part of the session.

The third session was held on 10-26-2023 in honour of World Acquired Brain Injury Day, where several puzzles were tested again, this time with corrections. The puzzles tested were Shahriar's Palace, The Cave of Wonders, The Last Voyage of Our Lady of Mercy, the Search for Moscow Gold and the History of Fogaça. There were 4 more participants.
The fourth session was with 10 participants external to ICTIA who heard about the project. A 2-hour session was proposed and they were divided into groups of 2-3 individuals per table.
Finally, the fifth session was carried out with users of the ASPAYM Castilla y León day centre who suffer from some type of spinal cord injury. The objective was to try the latest puzzles (Europe's Castle and Around the World in 80 Days). 5 participants attended.
During the sessions, facilitators and participants read aloud the narrative statements of each puzzle to learn the rules and the story behind it. In most cases, the silver testing methodology defined a table and experts in cooperative mode. In some cases, the activities were carried out in parallel, while in others the activities were carried out in turns while other participants gave advice, ideas and support.







CEIPES

The pilot phase started in October 2023, with the presentation of the project, showing the results produced by the consortium. The 10 puzzles developed by all partners were presented, two of each. Only 5 were present at the pilot and were tested by the participants.

Afterwards, the functioning of the 3D printer and the methodology used to develop the puzzles were explained. CEIPES also explained the use of gamification as a tool for non-formal educational activities. Furthermore, it was explained how to adapt Additive Manufacturing technology to different therapeutic needs.

The pilot was carried out with the target group of adults chosen by CEIPES, people with Special Learning Disorders. Specific Learning Disorders (SpLDs) represent a category of Neurodevelopmental Disorders that hinder the acquisition and utilisation of specific academic skills within areas such as reading, writing, mathematics, listening comprehension, and expressive language. These skills serve as foundational pillars for other scholastic learning. The devised puzzles were tailored to be inclusive for the designated target group, employing activities that circumvent the need for intricate mathematical operations. Engagement with these puzzles is anticipated to yield numerous advantages for the identified target population.

During the first session of the pilot project, there were 14 participants and they tested the following puzzles: “Around the World in 80 Days”, “Colapesce”, “The Story of the Fugaca” and “The Exit Within”.

The second session of the pilot project took place at the CEIPES offices in Palermo. In this session, there were 11 participants and they tested the following puzzles: “Around the world in 80 days”, “Colapesce”, “The story of the Fugaca”, “The Exit Within” and “Flaying the flag”.

In total, the pilot took place with 25 participants.

The pilot was supervised by two facilitators from the Si.da centre, psychologists and tutors for people with SpLD. Both followed the participants as they performed the puzzles.

At the end of each session, questionnaires were submitted to assess the quality of the puzzles.

In conclusion, the participants expressed their opinion positively. Several opinions were shared on how the puzzles could be improved for the future. Finally, the facilitators expressed the possibility of using the puzzles also in the future with the people that want to improve their cognitive and transversal skills.





CETEM

The methodology used by CETEM has been the same in all the workshops. First, we introduced all the participants to the project and its objectives. Then, we presented each of the puzzles individually, highlighting their storytelling. After that, we divided all the participants into small groups, with a maximum of 5 people, and distributed the puzzles among each of the groups. Once they had finished solving one puzzle, they were given the next one, so that all the participants had the opportunity to test and evaluate all the puzzles.

The first workshop was held with a group of 31 people at the “Las Herratillas” senior citizens’ centre. The participants in the workshop were retired people between 65 and 82 years of age, who attend this municipal senior centre for personal growth, training, physical and mental exercise, leisure, and free time activities.

CETEM selected the first of these target groups with the aim of promoting active ageing through the puzzles developed in the project. In this regard, they were a perfect match for our target group, since our objective was to help them to exercise their minds to keep them active. Brain games and puzzles provide an older person with the opportunity to use their critical thinking and problem-solving skills.

The participants had the opportunity to test three of the puzzles: ‘Fogaça’, ‘The last voyage of Our Lady of Mercy’ and ‘The search of Moscow’s gold’. They really enjoyed the activity, as they are not used to playing this kind of logic games. They found it tremendously interesting and asked us to

come back another day with new puzzles, so maybe we will repeat the workshop later on with the rest of the puzzles of the project.

The second workshop was held at the facilities of the Cancer Patients Association of Yecla, where a total of 8 participants had the opportunity to test three puzzles: 'The last voyage of Our Lady of Mercy', 'Cave of Wonders' and 'Fogaça'.

This target group was chosen by CETEM because of the suitability of the puzzles developed in the project for physical and neurological rehabilitation in cancer patients. This target group was chosen by CETEM because of the suitability of the puzzles developed in the project for physical and neurological rehabilitation in cancer patients, especially regarding the effects of neurological toxicity of chemotherapy and radiotherapy and its related cognitive impairment, and lymphedema, which is accompanied by stiffness, pain, loss of mobility and difficulty in mobilisation and flexibility of the arm, especially in the hand or wrist.

They were very interested and grateful in this workshop, since in the case of recovery after cancer, doctors focus more on physical rehabilitation and not so much on neurological rehabilitation. This often leaves patients alone with the aftermath, such as: short term memory loss, difficulty in maintaining attention, lack of concentration, reduced processing speed, difficulty in problem-solving, difficulty in learning and remembering new information

,

After the success of the first workshop with the Cancer Patients Association of Yecla, we returned to conduct a new testing phase with them, which was attended by participants who had already

attended the first workshop and also new ones. In total, 6 people tested the puzzles Palace of Shahriar and The search of Moscow's gold.

IDEC

The training sessions were meticulously planned and executed by IDEC S.A. as part of the D3PO project. The sessions were conducted in four phases, spanning May, June, July, and an additional session in October 2023.

Each session aimed to pilot test the 3D-printed puzzles—specifically "Flying the Flag," "The Exit Within," and "Colapesce."

The training format included hands-on engagement with the puzzles, allowing participants to interact with and solve the challenges presented. The adjustments and fine-tuning of the puzzles occurred based on participant feedback gathered during and after each session.

The participants in each session included individuals with learning difficulties alongside their special education teachers.

The workshops welcomed individuals with learning difficulties, creating an inclusive environment where they collaborated with their special education teachers. This inclusive approach ensured that the target group for the puzzles directly participated in the piloting process. The puzzles, designed to aid in the cognitive development of individuals with learning disabilities, were well-suited for this group. The presence of special education teachers further enriched the sessions by providing valuable insights into the participants' progress and engagement.

During the piloting of "The Exit Within," participants provided feedback indicating that the content of the steps to mental recovery was not entirely accurate. In response, IDEC S.A. undertook a significant fine-tuning effort, adjusting and refining the content to better align with the participants' needs and expectations.

For the puzzle "Flying the Flag," participants found a large percentage of the original quiz accompanying the cryptex to be too challenging. As a result, IDEC S.A. responded by cutting down the quiz, making it more accessible and enjoyable for the participants without compromising the educational value.

The feedback collected during the training sessions played a pivotal role in shaping the final versions of the puzzles, ensuring that they not only met the educational objectives but also catered to the specific needs and abilities of the target audience.







ROSTO SOLIDARIO

The pilot phase was carried out in collaboration with organisations which intervene directly with our target group – elderly people. In this way, we contacted Project Time and the Elderly Day Center of “Obra Social de S. Martinho da Gandra”. Before the sessions we explained the goals of the project and shared relevant information about the puzzles and the documents needed for the sessions with the person responsible for each organisation. The social workers of the organisations invited the participants to be part of the testing sessions, as they knew the elderly better.

Also, before the testing sessions, we held meetings with the professionals who would act as facilitators in the testing to explain the details of the puzzles. We tested the puzzles to understand how they worked and to anticipate difficulties that could occur with the target users.

For the process to be optimal, it was decided to deploy a total of 5 sessions with 71 elderly, aged between 60 and 100 years old.

The sessions took place in different places: in 4 "Senior clubs", in which people over 60 years old perform weekly social activities; and in the "Elderly Day Center", in which the elderly remain throughout the day getting the necessary basic care, but also cognitive and interpersonal stimulation.

In each workshop, first we briefly presented the D3PO project. We prepared "game tables" and at each table was a distinct 3D puzzle to be played as a team. The puzzles used in the testing Phase in Portugal were “Fogaça”; “Castle of Europe”; “The last voyage of Our Lady of Mercy”, “Colapesce” and “The search of Moscow’s Gold”.

In each session, the elderly were divided into small groups (teams), which were circulating through all the game tables in order to solve each 3D puzzle. In this way, they could always try more than 3 3D puzzles, which enriched their experience.

During the sessions, facilitators and participants read aloud the narrative statements of each puzzle to learn the rules and the story behind it.

The collection of signatures was carried out individually by puzzle, marking on them from which date they were made. To fill in the data, the help of the facilitators was essential since many even had difficulties writing.

After these 5 sessions we were contacted by another organisation to do one session with their elderly, which we did, but after the testing phase. In that session we took the opportunity of testing the puzzles again, even if we didn’t collect signatures and feedback questionnaires from the participants. However, it was important to verify one more time the power of playing these puzzles with elderly people.

Our target group was 71 elderly, but with different profiles.

The elderly of the 4 "Senior clubs", were people over 60 years old, actively ageing, as they are used to performing weekly social activities in groups. They still don't have significant motor or cognitive skills deficits despite their age.

The other profile was the participants of the "Elderly Day Center '', a centre in which the elderly remain throughout the day getting the necessary basic care, but also cognitive and interpersonal stimulation. These participants showed significant deficits in motor and cognitive skills, namely fine motor skills and locomotion impairments, some initial dementia stages, and other memory problems, etc. In this case, we tried to balance the profile of the participants in each team, so that they were more heterogeneous and contemplate some participants with less difficulties, to collaborate and help others that showed more impairments.

Without a doubt, they present a very interesting collection of participants for testing our puzzles.

The feedback has been very positive. In general, all the elderly were enthusiastic in this activity, considering the puzzles attractive, fun, but also useful to work interpersonal skills (teamwork) and cognitive skills (strategy and memory).

They were always verbalising the joy of playing again, as they did when they were children.

They have felt very lucky to be able to participate and are very interested in continuing with more puzzles and activities like the ones we present to them.

For the more complicated puzzles, the facilitators did some adaptations and gave more clues and provided extra help, so the participants could enjoy the experience of playing each puzzle.

Regarding difficulty, the opinion has been very diverse among the different participants. As expected, some exercises have been harder for those with the most severe disabilities and some support has been needed.

Another thing that was mentioned to be improved was with the fragility of some puzzles, like "Fogaça", because the pieces start to break after some use. Another suggestion was regarding the Europe Map, that is part of "The Caste of Europe" puzzle, since the pieces are too small and it was impossible for the elderly to do that part of the puzzle by themselves.

5. Recommendations

Creating puzzles, escape boxes, and escape rooms for therapeutic purposes requires a thoughtful and intentional approach. Incorporating storytelling can enhance the therapeutic benefits by providing context, engagement, and a meaningful framework for participants. Across this chapter we will present the workflow we followed to develop our puzzles, a small list of exercises that you can use for inspiration and finally a collection of general tips for the different phases of the process.

5.1. Brief considerations about level of difficulty

Before we dive into the contents of this chapter, it is relevant to settle some common ground since the concept of difficulty can easily become a struggle when starting to design.

The difficulty of puzzles is highly subjective and can vary significantly based on an individual's skills, experiences, and personal preferences. A person's skill level plays a crucial role in determining the perceived difficulty of a puzzle. What may be challenging for a novice could be relatively easy for an experienced solver. On the other hand, individuals with prior experience in solving similar puzzles are more likely to find them easier. Other factors can entail the performance during the process of solving, such as the emotional state, specific knowledge on the subject, cultural and language factors, etc. Constrains can also be used to artificially induce difficulty.

However, there is a standard scale of puzzle difficulty that rates them from 1 to 10. This scale is often used to assess and communicate the challenge level of various puzzles, games, and brain-teasers.

Level 1 (Very Easy): Puzzles at this level are extremely straightforward and can typically be solved with minimal effort or skill. They often serve as introductory puzzles for beginners or children.

Level 2-3 (Easy): Puzzles in this range remain accessible to most individuals and may require some basic problem-solving skills. They offer a gentle entry point for those new to puzzles.

Level 4-6 (Moderate): These puzzles present a moderate challenge, requiring more cognitive engagement and analytical thinking. Solvers need to connect different pieces of information or apply logical reasoning. They are suitable for a general audience with some puzzle-solving experience.

Level 7-8 (Challenging): Challenging puzzles can be quite complex and often require advanced problem-solving skills and creativity. They are designed for enthusiasts and those who enjoy intricate, thought-provoking challenges.

Level 9 (Expert): Expert puzzles are extremely difficult, demanding a high level of expertise in a particular area, like cryptic crosswords or advanced mathematics. They are intended for individuals with exceptional problem-solving skills and expertise.

Level 10 (Extreme): These puzzles are the most difficult and may be considered nearly impossible by most solvers. They often involve extreme complexity, intricate patterns, or rare knowledge. These puzzles are only meant for the most dedicated and skilled individuals.

The choice of difficulty level on this 1 to 10 scale should take into consideration the target audience and their preferences. For example:

- Children's puzzles should be easy to engage young minds and foster a sense of accomplishment.
- Puzzle games aimed at adults might offer a range of difficulty levels to cater to different skill levels.
- Educational puzzles can be adjusted based on the learning objectives and age group.
- Puzzle competitions or events should provide a variety of challenges to accommodate participants with varying skill levels.

The key to successful puzzle design is to provide a clear indication of the puzzle's difficulty level, so users can choose those that align with their skill and interest. Additionally, offering a variety of difficulty levels within a single puzzle game can cater to a broader audience and provide an enjoyable experience for all.

However when talking about therapeutical puzzles, it's important to consider the capabilities and potential disabilities of the users:

Visual Impairments: Puzzles could be accessible to individuals with visual impairments by providing alternative formats like Braille, tactile puzzles, or audio descriptions.

Hearing Impairments: Puzzles that rely on auditory clues should have visual equivalents or subtitles for those with hearing impairments.

Cognitive Impairments: Some individuals may have cognitive impairments that affect their problem-solving abilities. Puzzles for this audience should be designed with simplicity and accessibility in mind.

Fine Motor Skills: People with fine motor skill disabilities may struggle with intricate physical puzzles. Consider using larger pieces or adapting the puzzle to their needs.

Cognitive Disabilities: Puzzles for individuals with cognitive disabilities should be simplified and have clear, easily understandable instructions.

Cognitive Preferences: Some individuals may prefer easy puzzles due to personal preferences or limited time, while others may enjoy more challenging puzzles.

5.2. Our workflow

Creating 3D printable puzzles for therapeutic purposes with a storytelling element can be a fun and engaging way to provide rehabilitation.

Introduction and Storytelling:

1. Select a Theme: Choose a captivating theme for your 3D printable puzzle. For therapeutic purposes, consider themes like a magical forest, an underwater adventure, or a journey through time.
2. Create a Story: Develop a simple yet engaging story that relates to the chosen theme. This story will serve as the backdrop for the puzzles. For example, in a magical forest theme, the story could revolve around a quest to find a hidden treasure to heal the enchanted forest.
3. Set the Scene: Craft an introduction that presents the story to the patient. This can be done through a written narrative, spoken word, or a visual presentation. Explain the setting, the characters, and the main objective. For instance, introduce the patient to the magical forest, the talking animals, and the treasure hunt.

Designing the 3D Printable Puzzles:

1. Puzzle Elements: Develop a set of riddles that are integral to the story. Each part of the puzzle should be designed to fit together to form a complete picture related to the narrative.
2. Incorporate Challenges: Within each puzzle piece, embed therapeutic exercises or challenges that are suitable for the patient's needs. This could include exercises that enhance fine motor skills, cognitive abilities, or physical mobility.

3. Progressive Complexity: Ensure that the puzzles progressively increase in complexity as the patient advances through the story. Start with simple, easy-to-solve puzzles and gradually introduce more intricate pieces as the story unfolds.

Patient Engagement and Progression:

1. Integration of Storytelling: As patients solve each puzzle, incorporate elements of the story to keep them engaged and motivated. For example, after solving a puzzle piece related to the enchanted forest, reveal a part of the story about the patient's progress in the forest.
2. Track Progress: Monitor and record the patient's progress with each completed part of the puzzle and exercise. This data can help adjust the level of challenge and measure improvements.

Climax and Reward:

1. Develop a final, climactic riddle that ties together all the elements of the story. This puzzle should be more challenging than the rest and mark a significant milestone in the narrative.
2. Upon successfully completing the climactic puzzle, reveal a surprise element, which may be a hidden compartment within the final puzzle. Inside, place a figurine or a small item that signifies the accomplishment of the patient's journey and their therapeutic progress.

This workflow for creating 3D printable puzzles with storytelling provides a structured and engaging approach for therapeutic purposes, keeping patients motivated and connected to their rehabilitation journey through a captivating narrative. The surprise element serves as a rewarding and memorable conclusion to their efforts.

5.3. Example of exercises

If you don't know what type of exercises include in your creation, here is a list of more than 20 mechanisms that can be included in escape boxes and puzzles to create exciting and interactive experiences:

1. Labyrinths and Mazes: Incorporate physical or 3D printed labyrinth puzzles that require players to navigate a ball or object through a complex maze to unlock a compartment or reveal a clue.
2. Sliding Panels: Design puzzles with sliding panels that reveal hidden compartments or move to create new patterns, unlocking the next step in the puzzle-solving process.

3. Locks and Keys: Include traditional locks and keys or combination locks that require participants to find and input the correct codes to progress.
4. Hidden Compartments: Use hidden compartments within the box or puzzle, where players need to discover concealed elements, keys, or clues to advance.
5. Magnetic Mechanisms: Incorporate magnets to secure pieces or objects in place, requiring participants to manipulate magnets to unlock or reveal hidden information.
6. Gears and Cogs: Utilise gears and cogs to create mechanical puzzles that require players to turn or align them correctly to trigger actions or open compartments.
7. Rotating Wheels and Dials: Implement rotary elements that need to be turned to specific positions or aligned with markings to unlock secrets.
8. Screwing and Unscrewing: Use screws and screwdriver-like tools to secure parts of the puzzle. Participants must unscrew components to access hidden clues or compartments.
9. Sensors and Electronics: Integrate electronic components like sensors, lights, or sound effects that respond to specific actions or clues, adding an interactive element to the puzzle.
10. Magnetic Puzzle Pieces: Create magnetic puzzle pieces that need to be placed in the correct order or position to complete an image or reveal hidden information.
11. UV or Invisible Ink: Use invisible ink or UV-activated elements that require a UV light source to decode messages or uncover hidden symbols.
12. Optical Illusions: Incorporate optical illusions or visual tricks that players must decipher to reveal a hidden message or solution.
13. Sound Puzzles: Design puzzles that require players to listen for specific sounds or tones and respond accordingly to progress.
14. Scales and Balances: Create puzzles that involve weighing objects on scales or balancing elements to trigger mechanisms or reveal clues.
15. Reflection and Refraction: Use mirrors, prisms, or lenses to manipulate light and reveal hidden information or patterns.
16. Colour-Based Puzzles: Design puzzles that rely on colour-coding, where participants must match or mix colours to unlock the next stage of the puzzle.
17. Math-Based Puzzles: Include puzzles that require mathematical calculations, logic, or algebra to solve and progress.
18. Holograms and 3D Elements: Incorporate holographic images or 3D elements that participants need to interact with to unlock secrets.

19. Heat-Activated Elements: Use temperature-sensitive materials that reveal hidden messages or patterns when heated or cooled.
20. Memory: You need to remember certain combinations/positions to solve the puzzle but as you solve it, the solution gets hidden.
21. Zipper: Mechanism that transform circular motion into rectilinear motion or vice versa

5.4. Tips

Here is a collection of useful tips for the elaboration of the different phases of building puzzles/escape experiences.

5.4.1. Conceptualization.

Define the therapeutic objectives: Clearly articulate the specific therapeutic goals you want to achieve through the escape experience. Whether it's improving communication, fostering trust, or enhancing problem-solving skills, having well-defined objectives guides the design process and ensures that the experience is purposeful and impactful. Defining these objectives not only guides the overall design but also ensures that the experience is aligned with therapeutic principles. If you don't know where to start you can use the skill template we developed in this project.

Create your own rules: Every puzzle has their own rules. Sometimes they are part of the design and therefore the puzzle is self-explanatory but in other cases it is best to write them down to the user. In any case you must define them while you create the puzzle so the experience is not broken.

Understand your audience: Tailor the puzzles to the specific needs and preferences of the participants. Delve into the demographics of your target audience. Consider factors such as age, cultural background, and any specific therapeutic needs or challenges they might be dealing with. This understanding allows you to tailor the experience to the unique characteristics and preferences of the participants, enhancing its relevance and effectiveness.

Integrate storytelling: Develop a compelling narrative that serves as the foundation for the puzzle/escape experience. The storyline can provide context, relevance, and emotional engagement, making the therapeutic elements more impactful. Additionally, it serves as the cornerstone in therapeutic puzzle design. A well-crafted narrative provides a framework for the puzzles, immersing participants in a world where challenges become metaphors for real-life struggles. The power of storytelling lies in its ability to evoke empathy, trigger emotions, and establish a meaningful connection between the participant and the puzzle.

Choose appropriate themes: Carefully select themes that resonate with the participants and are congruent with therapeutic goals. Consider themes that mirror real-life challenges or personal growth journeys. The theme serves as a metaphorical bridge, helping participants draw parallels between the escape room challenges and their own life experiences.

Create symbolic puzzles: Design puzzles that symbolise or mirror real-life challenges. This approach allows participants to engage with therapeutic concepts in a symbolic and non-threatening way. The act of solving these puzzles can provide a sense of accomplishment and empowerment, reinforcing therapeutic principles.

Define a memorable experience: at least one of the tasks in the puzzle must propose a unique experience. This activity will be the signature of the puzzle. That way users will always remember your puzzle.

Include cooperative elements: Emphasise teamwork and collaboration by designing puzzles that require group effort. This not only encourages communication and cooperation but also provides an opportunity for participants to practise and strengthen interpersonal skills, contributing to the therapeutic objectives.

Provide opportunities for reflection: Build moments into the experience for participants to reflect on their actions, decisions, and interactions. Reflection enhances the therapeutic benefits by promoting self-awareness and allowing participants to connect the escape room experience to their personal growth journey.

Balance challenge and success: Find the right balance between challenging puzzles and achievable goals. Striking this balance ensures that participants are engaged and motivated throughout the experience. Success in solving puzzles contributes to a positive and empowering atmosphere, reinforcing the therapeutic aspects of the activity.

5.4.2. Design/production

Diagram: For sequential puzzles, it is very useful to draw a graph with all the steps to solve the puzzle. Then you can apply different metrics to your graph to easily identify if it enhances collaboration by working on multiple tasks at the same time or if it requires following one single path. Try to keep a balance between how wide and deep the graph is.

Geometry and tolerance: Ensure that puzzle pieces have adequate clearance and fit together snugly. Consider adding a small tolerance to account for variations in 3D printing.

Size and manipulation: Take into consideration that the pieces of the puzzle will have to be manipulated by your target group. This means they should have the right size to be utilised in a way that is comfortable or useful for the therapy.

Cost efficiency: Although you will need to create big enough puzzles to be manipulated, as the size of the puzzle grows, the expense in materials for 3d printers will also be higher. Try to maintain a balance.

Printability: Design pieces with overhangs and bridges in mind to minimise the need for support structures. This will make the printing process more efficient and reduce post-processing work.

Material selection: Select a suitable material filament material for your puzzle. The two biggest types of materials are for FDM and SLA printers. PLA is a common choice for its ease of use, but consider other materials like PETG for increased durability. Resin, on the other hand, is commonly used in SLA printers when you need to provide fine details.

Prototype printing: Before committing to a full print, consider printing a small prototype or a single puzzle piece to validate your design. This can save time and filament.

Reusability: Some cool puzzles may require breaking pieces or elements in the design. Although this is an original idea, it is best to minimise this system so you can reuse the materials multiple times.

5.4.3. Testing

Facilitate discussion: Plan debriefing sessions where participants can discuss their experiences and share insights. These discussions provide an opportunity to explore connections between the challenges within the escape room and real-life situations, facilitating deeper understanding and integration of therapeutic concepts.

Train facilitators: Equip facilitators with a clear understanding of therapeutic goals, the storyline, and the intended impact. Facilitators should be skilled in guiding participants through the experience and facilitating meaningful discussions.

Ensure accessibility: Consider the accessibility needs of participants to ensure inclusivity. This involves designing the experience in a way that accommodates diverse abilities, preferences, and potential sensitivities, ensuring that everyone can fully engage with the therapeutic escape room. Among some considerations:

- Prepare your design so it doesn't only rely on hue recognition.
- Ensure the difficulty matches the time goals and the reality of your target audience.
- Provide a system for optional tips when users get stuck. This can be performed with the figure of the facilitator but you can also create clue cards that the user can draw.
- Double check the mechanisms.
- Allow users to work in a comfortable way. When having big constructions, you can allow detachment of different pieces so exercises can be worked individually.

Gather feedback: Implement a feedback loop to collect insights from participants and facilitators. This ongoing process allows you to refine and improve the therapeutic escape experience based on real-world observations and experiences, enhancing its effectiveness over time.

Adaptation: try to adapt the use of puzzles to the user by creating a custom therapeutic protocol.

5.5. Therapeutic protocol

Elaborating a therapeutic protocol for rehabilitation using 3D printable puzzles is a creative and innovative approach to engage patients in the rehabilitation process. This method can be particularly effective for patients recovering from various physical and cognitive impairments. Below are the steps to create such a protocol:

1. Assessment and Patient Profiling: Identify the target patient group, their specific conditions, and the level of cognitive and physical impairments. Assess their interests, preferences, and abilities.
2. Define Therapeutic Goals: Determine the rehabilitation goals for each patient. Are you targeting physical, cognitive, or emotional improvement? Ensure these goals are specific, measurable, achievable, relevant, and time-bound (SMART).
3. Progressive Rehabilitation Plan: Develop a structured plan that outlines the progression of puzzles. Start with simpler puzzles and gradually increase complexity. Track the patient's progress over time.
4. Incorporate Cognitive and Physical Challenges: Depending on the patient's needs, incorporate cognitive challenges (such as memory, problem-solving, or pattern recognition) and physical challenges (like fine motor skills) into the puzzle designs.
5. Therapist Guidance: Train therapists and caregivers on how to use the puzzles effectively. They should provide guidance and encouragement to patients, adapting the protocol based on the patient's progress.
6. Monitoring and Adjustments: Regularly monitor the patient's progress and make necessary adjustments to the protocol. Ensure that the puzzles continue to challenge the patient without causing frustration.
7. Documentation and Reporting: Keep detailed records of each patient's progress, challenges, and achievements. This data will help in adjusting the rehabilitation plan and demonstrating the effectiveness of the therapy.
8. Feedback and Communication: Maintain open communication with patients and their families to get feedback on their experiences with the puzzles. Use this feedback to fine-tune the protocol.
9. Gradual Discontinuation: As patients reach their rehabilitation goals, gradually reduce the intensity and frequency of puzzle therapy. Transition them to more conventional rehabilitation methods if necessary.

10. Evaluation and Research**:** Periodically evaluate the effectiveness of the 3D puzzle therapy protocol through research and clinical studies. This will help in refining the approach over time.
11. Continuous Improvement: Continuously seek opportunities to improve the 3D printable puzzle therapy by incorporating new designs, technologies, or patient feedback.

It is very important to highlight that no two users or two patients are the same. That means that what may work for one user may not work for another. The key is to adapt your protocol to each case.

6. Bibliography

6.1 Bibliographic References

Bergland, Christopher (2011). T*he Neuroscience of Perseverance.* Available in:https://www.psychologytoday.com/intl/blog/the-athletes-way/201112/the-neuroscience-perseverance

Fissler, P. et al (2018). Jigsaw Puzzling Taps Multiple Cognitive Abilities and Is a Potential Protective Factor for Cognitive Aging. *Front Aging Neurosci, 10:* 299. doi: 10.3389/fnagi.2018.00299. Available in: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6174231/

Veno, Stefanie (2020). *Stress Relief Through Puzzles*. Available in https://www.med.unc.edu/phyrehab/wp-content/uploads/sites/549/2020/04/4.3.2020-Wellness-v2.pdf

Rafikovna, I. Z., Toshpolatovich, B., & Inomjonovich, M. R. (2022). THEORETICAL BASIS OF PREPARING FUTURE IT TECHNOLOGY TEACHERS FOR INNOVATIVE ACTIVITY. Web of Scientist: International Scientific Research Journal, 3(11), 803-812.

6.2 Webgraphy consulted

"Can't Meditate? Here's Why You Should Try Jigsaw Puzzles Instead". Available in

https://www.forbes.com/sites/nomanazish/2023/04/30/cant-meditate-heres-why-you-should-try-jigsaw-puzzles-instead/?sh=73487e8e3f1b

"Meet the neuroscientist who uses puzzles to help the brain heal after injury". Available in:

https://bigthink.com/neuropsych/brain-puzzles/?fbclid=IwAR2S2Xq3Wzg4A6mWpFTSP904lmNTwFMUrFR1xOefjzZ8-qXnMRkGvOOshlw

"Occupational Therapy Puzzles: Using Puzzles In Therapy". Available in:

https://www.cheshirefitnesszone.com/occupational-therapy-puzzles/?fbclid=IwAR13r1xX0vvP12q91yWVu9ndOSqBlYHpptJBJYryI67XLwOu_BcDgRa5Cz8

"Puzzles and wellbeing: are jigsaws good for mental health?". Available in:

https://www.printsinpieces.com/blogs/chat/puzzles-and-wellbeing-are-jigsaws-good-for-mental-health

"The 5 Benefits of Puzzles Solving for Adult". Available in:

https://www.dumblittleman.com/5-benefits-puzzles-solving-adult/?fbclid=IwAR1c-bO67HuJYW4Fd1C7g9BRKrsTl3XUo452EwWngesp2M1pboGmkjeiz1o

"The benefits of jigsaw puzzles for children". Available in:

https://www.orchardtoys.com/blog/the-benefits-of-jigsaw-puzzles-for-children_97026054.htm

"Why Children on the Autism Spectrum Love Jigsaw Puzzles". Available in:

https://diversityintoys.com/why-children-with-autism-love-jigsaw-puzzles/

www.neuro-connect.org/puzzles

DEPO

THANK YOU!