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The use of gamification for the improvement of reading and writing abilities and motivation in children with typical development and children with Specific Learning Disorders

Advisor
Prof. Paola Venuti

Student
Angela Cattoni

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DEDICATION

In the hope that this work may contribute to helping many children and their families, I dedicate it to my family, my beloved mother and father, because they have raised me aware that learning springs from every source — and that if you are curious and enthusiastic enough, you just have to look around to find that the world is full of wonderful opportunities to learn and grow.

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"Games give you a chance to excel,
and if you're playing in good company you don't even mind if you lose
because you had the enjoyment of the company during the course of the game."

— Gary Gygax

ABSTRACT

One of the main ways in which children learn skills, such as reading and writing, and develop creativity and sociability, is through play. Researchers are thus exploring *gamification*, namely the use of typical game elements in different and non-gaming contexts, including the educational one. Gamification is a methodology that originates from computer and serious games, and aims at redesigning activities to be more engaging, thus also developing intrinsic motivation. Furthermore, gamification has proven effective both with typically developing children and with children with Special Educational Needs (SEN).

Given that the current situation firmly indicates the need to engage and captivate learners, the present research aims to investigate whether gamification can improve motivation and reading and writing skills, in 8-to-10-years-old children. The design consists in comparing the effects of gamified Applications to that of equivalent, traditional pen-and-paper activities, in mixed and non-specific school groups. Furthermore, the effects are compared to those of an individualised clinical treatment for children with Specific Learning Disorders (SLD) — Developmental Dyslexia and Dysorthography in particular — using the same gamified Applications. In fact, although the neurocognitive causes of Developmental Dyslexia and Dysorthography are still hotly debated, researchers agree that the main challenge consists in the intervention, that is how to improve children's reading and writing fluency and accuracy while keeping motivation high.

Consequently, the research consisted of two studies. In the first study (Study A), a 12-hour gamified training at school was compared with an equivalent pen-and-paper training, both aimed at exploring the efficacy of gamified Applications and traditional activities purposefully designed to enhance linguistic skills (i.e., reading accuracy, reading speed, and writing accuracy). The results of this study showed significant improvements in linguistic fluency and correctness for both groups, with non-significantly greater effect of the experimental gamified training. Students belonging to the experimental groups also reported greater appreciation of the activities, although motivation did not function as a mediator for performance improvements in any of the groups considered.

The second study (Study B) aimed to explore whether improvements, after the use of gamified Applications, differ among children with neurotypical development, children with SLD, children with unspecified Neurodevelopmental Disorders, and bilingual children. Assessments upon training completion indicated greater improvements, even if not in a significant way, in reading and writing correctness in children with SLD, suggesting that an individualised and personalised training, designed on specific difficulties, can lead to major results. Also, participants in Study B reported to have highest degree fun during the activities, but motivation did not function as a mediator for improvements in performance either.

Gameful experience of the participants in both studies was also investigated through a questionnaire, the responses of which were related to improvements in learning performance. Results were not significant, but interestingly the aspects that were positively associated with learning outcomes were those related to competition and social experience dimensions, although they were the least present within the Applications used.

Overall findings highlighted promising effects of the training programs on children's linguistic skills and grade of engagement, emphasising the importance of integrated training and opening to future studies investigating the effects of gamified Applications on other skills and motivational aspects.

INTRODUCTION

Games are universal. They voluntarily involve individuals of all species, ages, backgrounds, and historical periods for pure recreational purposes (De Koven, 2013; Huizinga, 2014). Games involve and motivate individuals to act, to take risks, to persevere, to establish and reach increasingly challenging goals, to dedicate time and attention to the acquisition of new knowledge and skills. These aspects have a central function during everyone's process of developing, and games are, indeed, one of the main ways in which children can learn and develop essential skills for their everyday life (Lillemyr et al., 2011).

Furthermore, the activity of playing games is thought to be accompanied by a pleasurable emotional experience, thus being a potential welfare indicator (Held and Špinka, 2011), bringing both immediate psychological benefits and long-term benefits in the form of acquired skills such as critical and logical-strategic thinking, and socio-communicative and relational skills to manage conflicts within the group.

In relation to formal teaching-learning processes, research has also shown the effectiveness of games as tools to make students more active and participating (Nell et al, 2013), as well as concentrated, creative, motivated, and sociable (Barata et al., 2013; Brown et al., 2009; Prensky, 2001). Moreover, games are a safe environment in which learners can apply their own strengths and freely make mistakes, without the risk of repercussions and frustrations, leveraging on the effective learning methodology by trials-and-errors (Holland and Skinner, 1961), which could be particularly advantageous in case of difficulties. Not less importantly, games are also an important part of students' daily extra-school time and, therefore, they are a great way to convey the implicit learning of different skills.

Since the eighties, the analysis of the use of games in relation to learning processes has been fundamental to verify their effectiveness and impact on the improvement of skills in students. Furthermore, the idea that games are characterised by valuable principles not only for learning, but also for making each activity fun and engaging, is well established in several research fields (i.e., game design, human-computer interaction, education, etc.) and gave birth to conceptual constructs such as *funology*, *ludic design*, *serious games*, *game-based learning*, *edutainment*, *games for purpose*, and *gamification* (Breuer and Bente, 2010; Deterding, 2014).

According to literature, these are all slightly different concepts (Koivisto and Hamari, 2019; van Roy and Zaman, 2019). Yet, despite the increasing number of studies in the field, which recognises their value and potential (Bozkurt and Durak, 2018; Marsh, 2011), there are still no universally accepted definitions. For the purposes of the hereby presented PhD research project, the methodology of gamification is specifically considered as, since 2010, it has been incrementally studied and analysed and it offers promising ways of use in different contexts, especially in the educational one, which is also one of the least explored.

Gamification is generally defined as the use of game design elements in non-game contexts (Deterding et al., 2011). More recently, the definition of gamification has been centred on 'gameful experiences' and on the experiential quality of the gamified activity, instead of focusing on its elements (Hamari, 2019). Research, however, shows mixed results. Several studies highlight gamification efficacy (Aldemir et al., 2018; Egenfeldt-Nielsen, 2006; Gray et al., 2019; Hamari et al., 2014; Sailer et al., 2017; Xi and Hamari, 2019), showing its positive influence on engagement (Barata et al., 2013), motivation and results (Lister, 2015), learning (Landers, 2014), satisfaction (Armstrong and Landers, 2018) and fun (Lee et al., 2013). Furthermore, used as a didactic strategy, gamification has proven effective both with typically developing children and with children with Special Educational Needs (SEN) (Cuschieri et al., 2014; Dymora and Niemiec, 2019; Ifigenia et al., 2018). Nevertheless, other studies underline some critical elements or that

there is no empirical evidence of a positive impact (Dalmina et al., 2019; Hanus and Fox, 2015; Hyrynsalmi et al., 2017).

Certainly, the topic is hotly debated, and the hereby presented research fits right into the current state of the debate, attempting to move beyond the research that, for at least a decade, has focused on the effects of gamification elements, to embrace the more recent view of studies that focus on the psychological aspects influenced by a gameful experience (Hamari, 2019; Hassan and Hamari, 2019; Koivisto and Hamari, 2019). Moreover, either presented studies straddle a period in which the health emergency has led to an increase in the use of digital tools in the areas of learning and clinical intervention. However, it is crucial to find a balance in the use of these tools, enhancing their potential and limiting their risks, bearing in mind that, in any case, this should be a complementary type of intervention, potentially able to positively support traditional learning and rehabilitation.

Hence, the purpose of this research is to evaluate the effectiveness, in terms of motivation, engagement and improvement of reading and writing skills, of the use of gamified Applications. First, through a pilot study and in accordance with the literature (Furió et al., 2013a; Papadakis et al., 2016; Davis et al., 2017), the preference of using the tablet over the PC for different activities, including educational ones, was verified in a group of children between seven and twelve years old. Secondarily, employing well-being, cognitive, and linguistic abilities testing, a 12-hour gamified training compared with an equivalent pen-and-paper training, both designed to enhance linguistic skills, and a final assessment with eight to ten years old children within the school context, students' experience and learning were examined through grounded theory methods (Study A); a second study (Study B) involved children diagnosed with Developmental Dyslexia and/or Dysorthography, presented with a 12-hour individualised and personalised gamified training within a clinical intervention context. Such studies proved fundamental to understand limits and benefits gamification holds in order to better employ it at school and during rehabilitation programs.

The thesis is structured in four chapters. Chapter 1 grounds the research on a review of the literature on game research and, specifically, on gamification and its motivational potential also in the learning context. Chapter 2 is dedicated to cognitive developmental models of reading and writing and to Specific Learning Disorders (SLD), in particular Developmental Dyslexia and Dysorthography, as well as to interventions efficacy and to the clinical advantages of a digital training. Chapter 3 presents the experimental studies (pilot study, Study A and Study B), providing a detailed description of research objectives and hypotheses, the participants involved, the tools used, the experimental procedures and the analysis of the collected data. The thesis ends with Chapter 4, discussing the results and presenting further reflections on the limits and potential of the research project.

CHAPTER 1 – Of games and gamification

1.1 The universality of playing games

"*Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing*" (Huizinga, 2014, p. 1).

Even though the first evidence of games dates back to the Mesopotamian civilisations, the earliest reflections originate in ancient Greece, with Aristotle distinguishing the game from work and relating it to structured activities performed for no other purposes or immediate needs than those of the game itself (Abbagnano et al., 1974). Throughout history, the definition of games and of the activity of playing games have progressively changed and have been widely discussed and analysed, both at an ontological and epistemological level, by philosophers, psychologists, sociologists, and many other scholars who gave different definitions of these concepts.

According to recent literature in game studies field, the definition of "game" that is now accepted by the majority of researchers is: "any contest (play) among adversaries (players) operating under constrains (rules) for an objective (winning, victory pay-off)" (Ellington et al., 1982, p. 9). Yet, during the last decades, more definitions of game have been proposed than ever before, making research even less clear and cohesive (Stenros, 2017).

As for the activity of playing games, the definitions are also various. The *functional definition*, which describes play as an activity that is performed for its own sake and does not have any external goal (Smith, 2009), has prevailed since ancient times. Starting from Aristotle, the activity of playing games has been related to a voluntary activity somewhat closed, with its own rules and not aimed at a direct consequence in real life (De Koven, 2013; Huizinga, 2014). Furthermore, according to Huizinga, play can be defined as any activity performed for pure pleasure and without a specific purpose. Therefore, dancing, playing a musical instrument or acting can also fall into such a broad category.

On the other hand, the *structural definition*, which illustrates the types of behaviour that occur in play, looks at the actual activity, not at the purpose, and is at the basis of the pedagogy of play (Moyles, 2010; Smith, 2009). According to this approach, play fosters development by allowing children to put their knowledge to the test and increase their ability to communicate, and playing is therefore not seen as an activity as much as oppositional to learning.

Other authors favoured the *self-appraisal definition* of the psychological state that emphasises the perspective of the player who voluntarily attempts to overcome unnecessary obstacles in order to be amused by the activity of playing (Suits, 2019). Similarly, De Koven (De Koven, 2013) elaborated the individual's desire to play a game that is the voluntary act aimed at satisfying hedonic rather than functional needs.

Regardless of how it has been defined, the activity of playing games is a universal experience, in geographical, temporal and cultural terms, which involves different species throughout all periods of their life, and it has always been an unproductive, circumscribed and fictitious activity, characterised by fun, uncertainty of the outcome, and rules, voluntarily chosen for itself and for recreational purposes (Erenli, 2012; Ogan et al., 2010; Takaoka et al., 2011).

1.2 The role of play in education

In ancient times, the importance of playing games was recognised, but it remained a subject of study in the strategic and gymnastic fields (Huizinga, 2014). In more recent times, education was considered a moment of seriousness and disciplined activities, not 'contaminated' by the more amusing intentions of playing. It is thanks to Russeau and other modern pedagogists, such as Montessori, Dewey and Decroly, that play was introduced in the education of the child.

Play is often seen as opposed to 'seriousness', but as Huizinga (Huizinga, 2014) and Montaigne (de Montaigne, 1966) stated, play can absolutely include seriousness; indeed, children put all their efforts and commitment precisely when engaged in playful activities. Play is today proclaimed, in all international documents, as a prevailing and vital need in childhood and safeguarded as a right as it contributes to the cognitive, social, motor, and linguistic development of children (IPA - International Play Association, 2014; Lynch, 2015; OHCHR - Office of the High Commissioner Human Rights, 1989).

Through play, children learn to know themselves and others, experience creativity, develop cognitive abilities and executive functions and express themselves in total freedom. Games motivate to take risks, to act, to persevere even after failure, to establish and achieve increasingly challenging goals, to devote attention, time, and effort to acquire knowledge and skills indispensable for everyday life (Lillemyr et al., 2011).

Piaget (Piaget, 1959) recognised that play has as a central function in the complete development of the child, and the type of play in which children are engaged reflects their level of cognitive development:

1. stage of *functional play* (0-2 years) - corresponds to the development of sensorimotor intelligence through which the child progressively acquires control of the limbs and the ability to sensorially explore. In this first phase, imitation games play a significant role as they allow the child to learn to recognise and express emotions;
2. stage of *symbolic play* (2-7 years) - corresponds to the pre-operative phase of cognitive development during which the child learns to distinguish what overcomes the limits of reality from what is real and perceived through the senses. In this phase, the child is also able to perform the first logic-mathematical and space-time operations;
3. stage of *games with rules* (7-11 years) - corresponds to the cognitive acquisition of formal operations about concrete events and the progressive development of the concept of rule. At this stage, however, children tend to change the rules to their own advantage;
4. stage of *constructive play* (12 and up) - at this stage, children begin to think abstractly, and they code the rules thanks to deductive reasoning, seeing multiple possible solutions to problems.

Therefore, during the developmental age, play favours gross and fine motor development (Isenberg and Quisenberry, 2002); creativity and imagination as children create a world of their own in which they are emotionally involved and in which they can try different solutions in a risk-free environment (Freud, 1908); social development, through verbal and non-verbal communication (Saracho and Spodek, 1998); as well as emotional development as children share feelings with peers and experience others' point of view (Smilansky and Shefataya, 1990).

1.3 The importance of games for learning

Quite often, students are less engaged and attentive while in the classroom and spend much of their time thinking about non-study related topics (Murray et al., 2004). On the other hand, students themselves are more involved when they are engaged in tasks based on self-defined standards and desire for

improvement. It is therefore necessary to use alternative approaches to achieve greater involvement, keep motivation high and offer students the opportunity to be active throughout the learning process. One way could precisely be to integrate the traditional teaching process with the use of games and video games that can significantly improve students' level of motivation, which is the most critical issue of today's education (Ciolan, 2013).

Being a technological evolution of other forms of play, video games have great positive potential, in addition to their entertainment value, as they stimulate manual and perception skills, oculomotor coordination, fast problem solving, objectives and priorities management, as well as emotions management, and sometimes favour the learning of specific disciplinary knowledge. In addition, video games evaluate, in real time, the player's abilities and provide appropriate, direct, or indirect, feedback based on that information. Furthermore, the sense of gratification and discovery, aimed at involving the player and keeping the interest alive, are fundamental for self-esteem and self-concept (Griffiths, 2002; Schrier, 2014).

The history of video games started in 1947, with the first interactive game on an electronic display, and continued with the development of OXO by Alexander S. Douglas in 1952, but only in 1958 was the first computer game created, Tennis for Two, conceived as an entertainment product. Over the years, both interest growing in academic research and improvements in information technology, favoured the development and spread of video games also for more serious purposes, such as informing, training, and teaching.

The use of games for educational purposes has been studied since the eighties, and, in this regard, several concepts emerged: *entertainment education*, *edutainment*, *games-based learning*, *serious games*, and *gamification* (Breuer and Bente, 2010). Although these concepts are different from each other (see Table 1 for some examples), they all have the intrinsic goal of using games for purposes that go beyond pure entertainment and to support learning in a playful way, thanks to "activities with the structure, spirit and rules of a game to make learning fun and motivating" (Bonaiuti, 2014, p. 81).

Of all these concepts, the present research aims at analysing the efficacy of gamification which, since 2010, has gained more attention in the educational and rehabilitation fields (de Byl, 2013).

Table 1. Comparative analysis table

Comparison	**Gamification**	**Game-based learning**	**Serious game**
Purpose	Uses game-like features in a non-game context, to make it more fun and engaging	Involves actual gameplay, with defined learning outcomes, to fulfil learning objectives	Designed to provide training, practice and interactions that are engaging
Objective	Motivate	Educate	Educate
Benefits	● Instant feedback ● Prompting behavioural change	● Fast strategic thinking, problem solving ● Hand-eye coordination development	● Social development ● Focus on autonomy
Examples	*Gimkit, Classcraft, Class Dojo, Duolingo, Kahoot!*	*SimCity, Civilization, Minecraft, Portal*	*Dragon Box Elements, Pacific, Pulse!!*

1.4 Gamification

The term 'gamification' was first coined in 2002 by an English programmer, Nick Pelling (Pelling, 2011), and it referred to the process of changing interfaces in order to make them more fun and game-like. Afterwards, the term was adopted more widely, and the related research increased starting from 2010, thanks to the work of Jesse Schell and the publication of his book The Art of Game Design (Schell, 2008).

The most widely used definition of gamification refers to the use of game design elements (Zicherman and Cunningham, 2011; Deterding et al., 2011; Burke, 2012; Werbach and Hunter, 2012) in a non-gaming environment (Deterding et al., 2011; Burke, 2012; Werbach and Hunter, 2012) to improve user engagement and experience (Zicherman and Cunningham, 2011; Burke, 2012; Huotari and Hamari, 2012). According to this definition, the word 'game' refers to its objective oriented nature and to the presence of rules; 'design' refers to a specific design process; the 'elements' indicate the typical characteristics of games that distinguish them from other activities; and the 'environment' has its only constraint in the exclusion of game environments themselves.

Table 2. Definitions of gamification (based on Spanellis et al., 2016, p. 4)

Definitions of gamification	
(Pelling, 2011, p. 1)	*Applying game-like accelerated user interface design to make electronic transactions both enjoyable and fast.*
(Zicherman and Cunningham, 2011, p. xiv)	*The process of using game-thinking and mechanics to engage users.*
(Deterding et al., 2011, p. 1)	*The use of game design elements in non-game contexts.*
(Burke, 2012, p. 1)	*The use of game mechanics and game design techniques in nongame contexts to design behaviours, develop skills or to engage people in innovation.*
(Werbach and Hunter, 2012, p. 26)	*The use of game elements and game-design techniques in nongame contexts.*
(Huotari and Hamari, 2012, p. 19)	*A process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation.*
(Werbach, 2014, p. 266)	*The process of making activities more game-like.*

Gamification makes use of some components of game design such as scores, prizes, leaderboards, levels, progress bars, challenges, ratings, etc. (Vassileva, 2012; Spanellis et al., 2016). Several studies tried to classify these elements, in most cases by their level of abstraction, but in literature there is still disagreement, both in the levels and in the terminology (see Table 3). All the authors, though, mentioned the most commonly used gamification affordances that are points, badges and leaderboards, constituting

the 'PBL' triad and the basic building blocks that users see and interact with (Spanellis et al., 2016; Koivisto and Hamari, 2019).

Table 3. Classifications of gamification elements (based on Spanellis et al., 2016, p. 6)

Source	Game elements	Examples
(Zicherman and Cunningham, 2011)	Mechanics	points, levels, progression bar, leaderboards, badges
	Dynamics	pattern recognition, collecting, surprise, creating order, gifting, flirtation, recognition for achievements, leading others, fame, heroism, gaining status, growing
	Aesthetics	sensation, fantasy, narrative, challenge, fellowship, discovery, expression, submission (Hunicke et al., 2004)
(Werbach and Hunter, 2012)	Components	achievements, avatar, badges, boss fights, collections, social graph, virtual goods, combat, content unlocking, gifting, leaderboards, levels, points, quests, teams
	Mechanics	challenges, chance, competition, cooperation, feedback, resource acquisition, rewards, transactions, turns, win states
	Dynamics	constrains, emotions, narratives, progression, relationship
(Deterding, 2012)	Interface design patterns	badge, leaderboards, level
	Design patterns and mechanics	time constraint, limited resources, turns
	Design principles and heuristics	enduring play, clear goals, variety of game styles
	Game models	MDA, challenge, fantasy, curiosity, game design atoms, CEGE
	Game design methods	playtesting, play-centric design, value conscious game design
(Blohm and Leimeister, 2013)	Mechanics	documentation of behaviour, scoring systems, badges, trophies, rankings, ranks, levels, reputation points, group tasks, time pressure, tasks, quests, avatars, virtual worlds, virtual

		trade
	Dynamics	exploration, collection, competition, acquisition of status, collaboration, challenge, development / organization, motives

Video games are, indeed, complex systems structured on various elements, which can be summarised in what Schell defines as the Elemental Tetrad (Schell, 2008): Story, Aesthetics, Mechanics, and Technology. The first provides the essential elements for understanding game objectives and keeping the player narratively engaged; aesthetics facilitate a sustained level of immersion; and mechanics and technology, which together define player interaction, set respectively the basic rules of the game and the apparatus with which the player interacts.

Other studies that constitute a fundamental contribution to the identification of an adequate theoretical framework, are the work of Hunicke and colleagues, who formulated the MDA framework – Mechanics-Dynamics-Aesthetics (Hunicke et al., 2004) and the participatory practices in Menestrina's research (Menestrina, 2017), which resulted in the PEP – Participatory Elemental Pentad.

In the MDA framework, Mechanics represent algorithms and rules that specify every possible user's action; these give rise to Dynamics, which embed emergent interactions between the system and players and that, eventually, transform into experiential Aesthetics, that are the emotional user's response to game components and dynamics.

Elements of both MDA framework and Elemental Pentad are strongly interrelated, coexist symbiotically, and constitute the basics of multi-dimensional design processes, and those of Schell and of Hunicke and colleagues are certainly valuable and crucial methodological contributions to the gamification research field. Yet, they did not take into consideration an essential element — especially important for the educational field: the Purpose element, which has been instead taken into consideration by Menestrina.

Purpose is a component which can be either intrinsic to the game, when the activity itself is a source of knowledge and training (i.e., the intrinsic and specific purpose of Duolingo is to learn a foreign language); or extrinsic, when it is separate and not explicitly linked to activities (it is the case of most cognitive training Applications) (Gee, 2003; 2010). Purpose is what gives usefulness to a hedonic design; in a gamified system, the objective, which in learning contexts is usually a long-term commitment and requires persistence in order to have results, is achieved through an enjoyable process (Koivisto and Hamari, 2019).

More recently, the definition of gamification significantly evolved, referring to any product, service, system, and activity, both analog and digital, which afford positive experiences as games do (Hamari, 2019). This transformation process, supported by social, cultural, and technological developments, can be either intentional, aimed at facilitating changes in behaviours or cognitive processes by employing game design principles, or unintentional, stemming from the increasingly role of games in the society. In any case, this most recent definition of gamification no longer focuses on the elements of game design, since that would suggest that the experience of playing is intrinsic to points, badges, leaderboards, etc., rather on the experiential quality of playing, on the 'gameful experiences' (Xi and Hamari, 2019; Hamari, 2019).

1.5 Gamification and motivation

Within the psycho-educational context, in which gamification is gaining significant attention (Dicheva et al., 2015; Seaborn and Fels, 2015; Majuri et al., 2018) with the name of 'gamification of learning' and 'educational gamification' (Seaborn and Fels, 2015; Bozkurt and Durak, 2018; Majuri et al., 2018; Dalmina et al., 2019), an important and commonly used theoretical framework to explore player's motivation is the Self-Determination Theory (SDT) (Deci and Ryan, 1985; Deci and Ryan, 2000; Ryan and Deci, 2000; Rigby and Ryan, 2011).

SDT is an approach to human motivation and personality that concerns the inner resources for personality development and behavioural self-regulation, as well as the intrinsic tendencies and the innate psychological needs that, along with environmental conditions, are at the basis of people's motivation (Deci and Ryan, 2000). The basic principle of this theory consists in the assumption that people function as driven by the satisfaction of some fundamental, innate, intrinsic, and universal needs, which favour growth and well-being. Such primary needs are distinguished in:

- need for *competence*, or the need to perceive oneself as effective and able within a given context. It describes the feelings of being effective in interactions within a context and being able to experience opportunities to train and express one's skills in order to be successful;
- need for *autonomy*, or the need to have and maintain control over one's life. It represents the desire to feel responsible and to have control over one's behaviour;
- need for *relatedness*, or the universal need of the individual to interact and to be in contact with others. It refers to the feelings of being connected to others and taking care of them, being accepted by a community and being part of it.

Gamification is used with the main purpose of involving users more and motivating them in interacting with an application or service by making it more fun to use (Deterding et al., 2011). The need for competence is linked to the desire of the individual to be able to successfully reach a goal and to feel expert in a certain context. To leverage this need, gamification offers activities that allow the user to leave their comfort zone and enhance their skills. The tasks have a gradually increasing difficulty, so that users can test themselves, improve their skills and acquire new ones.

As for the need for autonomy, individuals wish to feel independent, they should not perceive the presence of external constraints or pressures and behaviour must be determined by a free choice. Thus, gamified systems aim to offer a variety of meaningful and supportive challenges that are not perceived as mandatory or externally controlled; otherwise, the sense of autonomy would be reduced, and feelings of anxiety and concern could emerge.

Regarding the need for relatedness, that is the desire to relate to others that gives the individual a sense of value and increases psychological well-being, it is satisfied when individuals can share their experiences and set common goals. Therefore, gamified systems aim to promote social interaction by increasing the sense of connection and belonging, even when users play individually.

Central to the SDT approach is also the distinction between autonomous, or intrinsic, motivation, and controlled, or extrinsic, motivation.

Intrinsic motivation, that concerns the intrinsic tendency to seek novelty and challenges, to train one's abilities, to explore and to learn, is considered the most productive drive of human behaviour (Deci and Ryan, 2000). This concerns actions conducted based on one's own will and personal choice. It comes into play when individuals act based on their own will, for the pleasure of acting in a specific context. Within the educational context, intrinsic motivation and free will are considered fundamental for successful learning.

In 1985, Deci and Ryan also defined the Cognitive Evaluation Theory (CET) to explain the influences of social and environmental factors on the variability of intrinsic motivation, whereby the effects of rewards, feedback and other external elements may hinder or increase it, in particular in relation to the needs of competence and autonomy.
Some studies have shown that positive feedback improves intrinsic motivation only when people experience a sense of autonomy, while negative feedback decreases it (Deci and Wayne, 1972), and such effects are mediated by perceived competence (Vallerand and Reid, 1984). Furthermore, opportunities for self-directionality have been identified as effective for improving intrinsic motivation, as they give individuals a greater perception of autonomy and competence (Deci and Ryan, 1985). Relatedness is also important and produces further variability on intrinsic motivation which is more likely to thrive in contexts characterised by a sense of security and relationship (Ryan and Grolnick, 1986).
Extrinsic motivation, on the other hand, refers to actions started under external pressure or obligation and that represent most of the individuals' life (Ryan and La Guardia, 2000). SDT identified the processes by which non-intrinsically motivated behaviours can become self-determined, and the ways in which the social environment exerts influence on these. For this reason, Deci and Ryan (Deci and Ryan, 2000) developed the Organismic Integration Theory (OIT), aimed at categorising the diverse types of extrinsic motivation and contextual factors that promote or hinder behaviour internalisation and integration.
According to this approach (Fig. 1) — whose central theoretical assumption is that it is not the quantity of motivation that assumes a predictive and explanatory value on the future behaviour of individuals, but the diverse types of motivation — there are three general motivational states:

1. *amotivation*, which concerns situations in which individuals act without motivation, intention, and control over their own behaviour;
2. *intrinsic motivation*, which derives from an internal regulation and pushes the individual to involve in an activity because it is interesting and motivating;
3. *extrinsic motivation*, due instead to the presence of an external stimulus that encourages the individual to implement the desired behaviour.

Extrinsic motivation is further divided into four categories, based on the degree of control over the action (Legault, 2017; Ryan and Deci, 2000), which can be determined by several types of regulation:

- *external* - behaviours aim at satisfying an external demand or earning a possible reward;
- *introjected* - behaviours are supported by regulatory factors that are inherent, but not fully accepted;
- *identified* - indicates a conscious assessment of a behavioural goal, so that the action is accepted or deemed personally important and, therefore, deliberately initiated;
- *integrated* - occurs when behaviour activation derives from a clear identification of purposes, interests and objectives that are integrated with each other and with the individual's identity. This differs from intrinsic motivation, as the behaviour is not determined by an interesting activity, as can be, for example, the one concerning the gaming experience.

External and introjected regulations are generated by a controlled motivation that tends to vanish easily when the external stimulus is removed, whereas identified and integrated regulation, as well as intrinsic motivation, depend on a lasting autonomous motivation that guarantees a better performance in different contexts and increases psychological well-being (Gagné and Deci, 2005). The internalisation process is, therefore, essential to ensure that behaviours are increasingly regulated from within and depends on the degree to which the basic psychological needs of autonomy, competence and relatedness are satisfied.

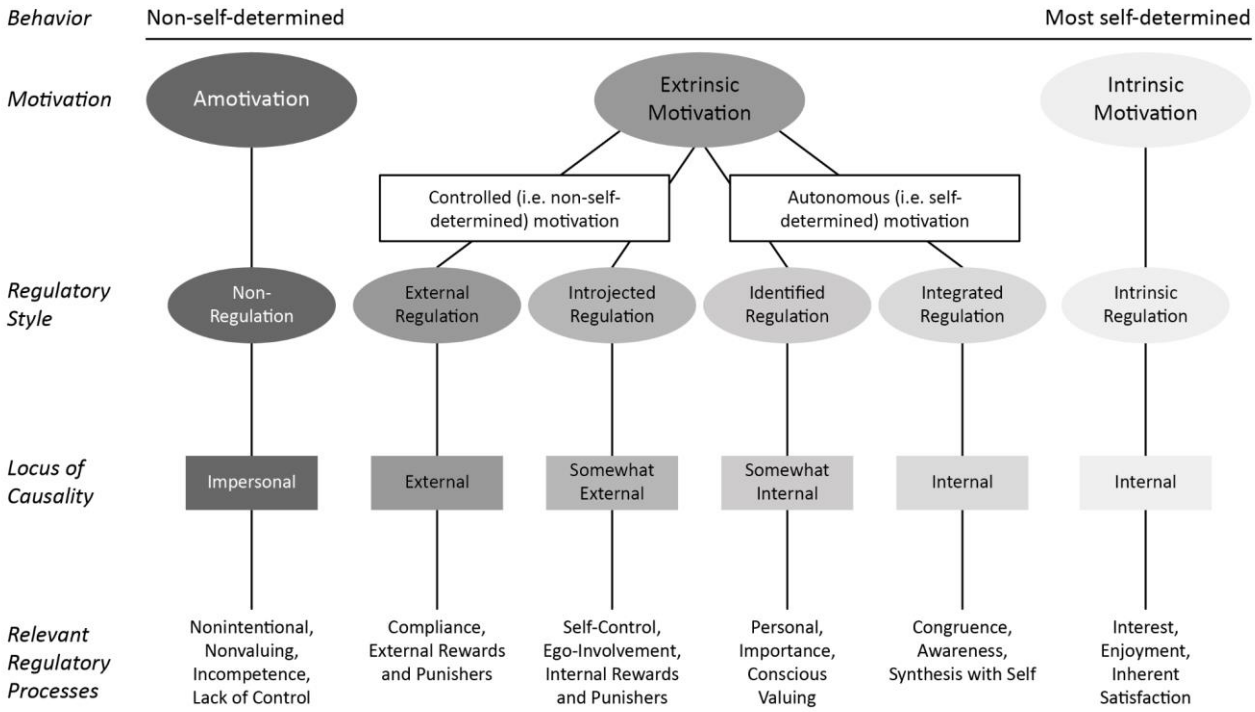

Figure 1. The Self-Determination Continuum showing types of motivation with their regulatory styles, loci of causality and corresponding processes (based on Legault, 2017)

Several studies demonstrated that more autonomous extrinsic motivation is associated with greater involvement (Connell and Wellborn, 1991), better performance (Miserandino, 1996), lower school dropout (Vallerand and Blssonnette, 1992), learning higher quality (Grolnick and Ryan, 1987), and better teacher ratings (Hayamizu, 1997).

In accordance with the SDT, some authors suggest how gamification promotes an extrinsic motivation between the dimensions of introjection and identification (Deci and Ryan, 1985; Gooch et al., 2016; Ofosu-Ampong, 2020); the player is thus motivated by self-improvement, even if rewarded in an extrinsic way with badges and other typical game elements. This is pedagogically relevant and supports the educational potential of gamification to increase motivation in students (de Sousa Borges et al., 2014; Vezzoli and Tovazzi, 2018), as it is considered one of the most crucial factors leading to academic success (Taylor et al., 2014).

1.6 Gameful experience

In literature, there are many positive results regarding the use of gamification and the satisfaction of needs related to motivation (van Roy and Zaman, 2019; Peng et al., 2012; Bormann and Greitemeyer, 2015), however they reflect the type of behaviours and outcomes desired to observe (Nah et al., 2013), as gamified tools are defined a priori by the designer, and they return only a partial picture, as they investigate a limited set of gamification features and/or intrinsic needs (Xi and Hamari, 2019). Moreover, some studies assume that elements external to users act solely as extrinsic motivators, thus decreasing intrinsic motivation (Hanus and Fox, 2015), whereas, according to SDT, extrinsic motivation can be internalised and integrated (Ryan and Deci, 2000).

On a global level, gamification includes three main elements (Hamari et al., 2014; Koivisto and Hamari, 2019) that are connected to each other:

- motivational implementations (or affordances, that are the qualities of an object allowing the interaction with it), that refer to the various game elements and mechanisms, and help induce typical gameful experiences within different systems;
- psychological outcomes, that indicate psychological experiences, such as competence, autonomy, and relatedness, or fun and involvement, which games and gamification generally promote;
- behavioural outcomes, that concern activities and behaviours supported through gamification, such as better learning outcomes.

Overall, the motivational performances implemented in a system lead to psychological outcomes, which, in turn, allow to achieve behavioural results. All these elements are located within a certain context (Fig. 2) that refers to the activity that is gamified (i.e., education, trade, work, health, etc.). Moreover, in addition to the attention paid to the role of the context being gamified, also the qualities of the users who will interact with it are important, in order for gamification to be effective (Hamari and Tuunanen, 2014).

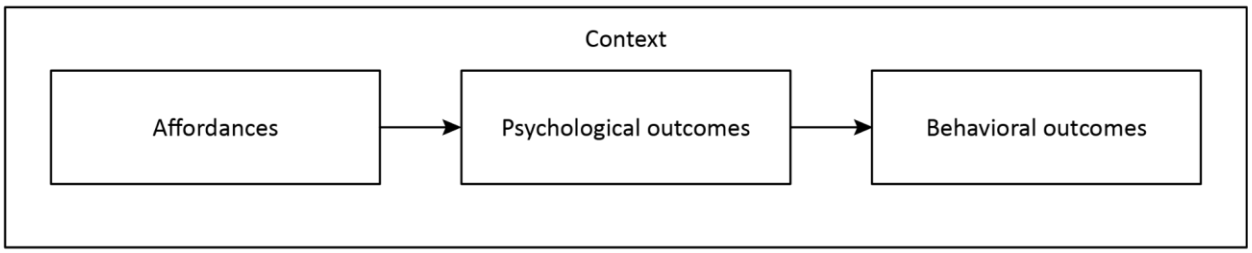

Figure 2. The conceptualisation of gamification (based on Koivisto and Hamari, 2019)

In a recent study (Xi and Hamari, 2019), the relationship between user interactions and the elements of gamification was investigated. The authors identified three primary categories that reflect the key features of the game design aimed at increasing player motivation:

- immersion-related features (i.e., avatar, storytelling, customisation, etc.) that mainly attempt to immerse the user in a self-directed activity (Bormann and Greitemeyer, 2015; Kim et al., 2015; Koivisto and Hamari, 2019; Peng et al., 2012; Schneider, 2004) and induce autonomous thinking (Stefanou et al., 2004);
- achievement-related features (i.e., points, badges, feedback, leaderboards, tasks, etc.) that measure players' in game behaviour (Sailer et al., 2013) and increase goal-oriented behaviour (Hamari, 2017; Hamari et al., 2018) through cumulative feedback (Rigby and Ryan, 2011);
- social-related features (i.e., groups, messages, social network, etc.) that provide users a strong feeling of connectedness and reinforce interpersonal relationships (Shiau et al., 2018).

Based on this differentiation, the relationship between gamification features and the three primary psychological needs of SDT (autonomy, competence and relatedness) is evident, even if the results indicated that only immersion-related gamification features were positively associated with the related need satisfaction (i.e., autonomy), whereas achievement- and social-related features were positively associated with all kinds of need satisfaction, suggesting that game design should consider different gamification features in order to motivate users.

In a further study (Sailer et al., 2017), game design elements were varied and analysed in relation to their effect on the satisfaction of basic psychological needs according to the SDT. The results showed how badges, rankings and performance charts positively impact the need for competence. This is consistent with theoretical considerations on the potential of these features to function as feedback elements (Peng et al., 2012; Rigby and Ryan, 2011), and to contribute to an increase in task significance. Instead, avatars, storytelling, and teammates influence social experiences, as they introduce a shared goal (Rigby and Ryan,

2011). Lastly, perceived autonomy was not modulated by any aspect of considered game design, and it seemed to depend on more important decision-making processes (Peng et al., 2012). The authors therefore confirmed that the game design elements analysed can satisfy basic psychological needs but suggested that it is necessary to ensure players' awareness of such features to achieve the desired results, especially in certain groups of individuals. In fact, gamification features can satisfy needs and guide intrinsic motivation, but some elements function as both extrinsic and intrinsic motivators for certain individuals, depending on the context (Deterding, 2011).

These interesting findings suggest that positive effects of gamification can be achieved by addressing a multilevel design process. Although it is certainly fundamental to analyse the effects of the different gamification affordances, assuming that this construct can be broken down into single elements which presumably produce one — and only one — motivational effect across users, the fact that the motivational or functional valence (Deci and Ryan, 2002) of an element also depends on its situationally appraised meaning cannot be ignored. Moreover, the same gamification element can activate several motivational processes at the same time (Antin and Churchill, 2011), and, vice versa, the same motivational process can be supported by different elements.

Any motivational valence, also, emerges from the user experience, that is the overall interaction that the user has with an artefact in a particular context (Nicolás et al., 2011). User's characteristics, such as emotions, values, and previous experience, determine the modalities according to which the user perceives the artefact — that should be usable and useful (Forlizzi and Ford, 2000; McGrenere and Ho, 2000) — and the context — that should be facilitating, appropriate and engaging (Skinner and Belmont, 1993). Thus intended, (gameful) user experience is not an objective feature, but a relational quality of both the artefact and the user (Nielsen, 1993).

1.7 Advantages of gamification for learning

Technology has been transforming human society and activities for centuries (Jerald, 2009), but despite the fact that technology has also been incorporated into education both as a tool to support learning and as a learning object to meet the demands of a rapidly evolving and increasingly technological world, 21st century students have been unable to receive efficient and engaging education due to misuse of such technology. In fact, most of the time, technology is used in traditional teaching models that do not fully exploit its potential; it is used as a mere *medium* for the transmission of linear, teacher-centred information (Figueroa-Flores, 2016).

Young generations, who have grown up in close contact with information technologies and, even more, with video games, require a spur during teaching-learning activities, in order to keep attention and motivation high, as they potentially already have access to new knowledge through use of Internet on mobile devices (Blair, 2012). Within the school environment, teachers should try to respond, through different teaching strategies, to the educational needs of students, as well as to increase their motivation and involvement in favour of active learning and to foster positive learning experiences (Aura et al., 2021). Game, video games or even just game elements can thus be an important factor to influence the behaviour of students, to involve them and to also create a welcoming, inclusive, and collaborative learning environment (Aura et al., 2021), as perceived feelings of social support can have the long-term effect of increasing interest towards further education (Ryan and Patrick, 2001). Video games are a powerful medium for achieving educational goals thanks to narratively rich worlds in which students function as adventurers, scientists, writers, mathematicians, and so on, who engage complex tasks to transform the virtual world itself. If properly designed, video games provide tools, problems, experiences,

perspectives, and consequences to ensure that learners develop both skills, such as problem solving, collaboration, and communication, and content understanding (Barab et al., 2007; Figueroa-Flores, 2016). According to some researchers (Lucisano et al., 2013), the indispensable characteristics that a game must possess to ensure learning are: being stimulating, that is, requiring mental and physical commitment; being continuous and close to the experiences and abilities of individuals; and being progressive and varying continuously in order not to become automatic or boring. In addition, there should always be a reward dynamic, which represents a positive reinforcement of the action.

In this sense, gamification can also support the learning process of students. In the educational context, both formal and informal, gamification is defined as the use of game mechanisms, aesthetics, and interaction, thanks to which students feel involved, motivated to action and to solve problems (Kapp, 2012; Seaborn and Fels, 2015).

A recent review (Colón et al., 2018) revealed how gamification, applied to education, can generate important benefits for students, such as increased motivation, immersion to plan and anticipate new situations, commitment and sociality through interaction and interactivity. In addition, there are different types of elements that make education more engaging and effective for students, such as the use of positive feedback that pushes students to be more interested, motivated, and stimulated in studying (Muntean, 2011).

Gamification is widely used in formal educational contexts, especially in university courses (Caponetto et al., 2014), mainly to increase motivation and participation, as well as to support content learning in specific subject areas. Furthermore, it appears that gamification is useful for the development of soft skills, such as the promotion of participatory and collaborative approaches with peers, the development of autonomous learning, the integration of exploratory approaches to learning and the enhancement of students' creativity.

Even at lower school grades, gamification finds room for application. The study by Furió and colleagues (Furió et al., 2013b) is an example. In a class of thirty-eight children, aged eight to ten, the effectiveness of a traditional lesson compared to the use of a computer game was evaluated for the study of a science topic relating to the water cycle and in terms of perceived satisfaction. The computer application consisted of seven mini-games, linked by a common narration and the presence of a guiding character represented by a water drop, during which feedback and rewards were provided. The pre-test and post-test analysis identified significant progress in learning, regardless of the method used. However, greater learning effects emerged for those who used the computer game, even though the data were not significantly different. Instead, in the analysis of the motivational aspects, the most satisfactory outcomes for learning came through playing and children reported a preference for the game and the willingness to reuse such modality to study other subjects as well.

In a subsequent review, various research relating to the application of gamification for the enhancement of cognitive skills, such as working memory and attention-executive functions, were analysed (Lumsden et al., 2016). It emerged that the use of gamification led to an increase in the effectiveness of the intervention and a better perceived experience by participants, compared to more traditional methods (Ninaus et al., 2015).

Afterwards, an improvement in argumentative writing skills and an increase in the online publication of comments in students at Secondary School was reported thanks to the use of a blended learning approach, which involved teaching through gamification compared to teacher's direct instructions (Lam et al., 2018). According to the teacher, the use of message labels and writing examples were particularly useful as they could specifically improve students' self-control and self-correction, aspects that improve outcomes when present during the act of writing (Graham and Perin, 2007).

In another study (Bal, 2019), gamification was used to promote problem solving and increase writing skills. The methodology increased the interest of First Grade Secondary School students towards the writing course, facilitated class management, supported collaborative work, and developed creativity.
In order to explain the influence of gamification in education, Landers (Landers 2014) developed the Theory of Gamified Learning (Fig. 3), that is the use of game features, outside their typical context, aimed at influencing behaviours or attitudes related to learning. According to this theory, gamification must successfully alter a learner's intermediate behaviour or attitude related to learning, to be efficient. This influence can occur directly through the moderation process, when a behaviour that will increase learning outcomes is encouraged by pre-existing instruction, or through the mediation process, when the behaviour that will itself improve learning outcomes, is encouraged. Hence, in order to engage and motivate 21st century learners, teachers have to plan accordingly.

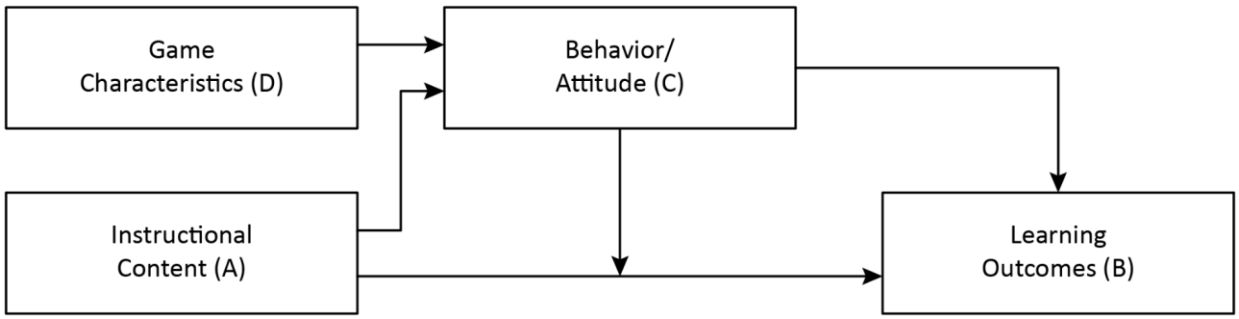

Figure 3. Theory of Gamified Learning (Landers, 2014, p. 760)

In the work of Mohamad and colleagues (Mohamad et al., 2018), in order to adequately implement gamification within educational contexts, involve users more, and design individualised learning plan, some steps are recommended (Fig. 4): determination of students' intelligence; definition of learning objectives; structuring of learning experience with contents and activities; application of interactive design elements and typical game mechanisms.

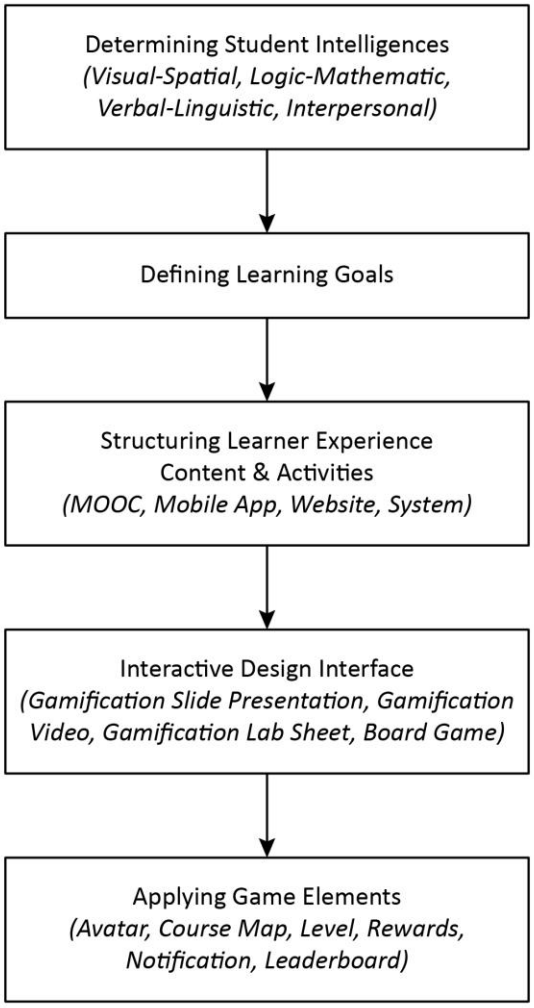

Figure 4. The gamification approach in education (Mohamad et al., 2018, p. 28)

In gamification research related to the educational context, the most frequently used design elements are visual aspects, social commitment, freedom of choice, possibility of failure and rapid feedback, while the most popular game mechanisms are points, badges, rankings, levels and progress bars (Dicheva et al., 2015; Dalmina et al., 2019), which act with different motivational effects on users based on their specific personality (Codish and Ravid, 2014) and are associated with specific individual behaviours (Karanam et al., 2014), depending on whether the involvement is superficial or deep (Kapp, 2012).

Therefore, when using gamification for learning purposes, specific game elements should be chosen paying attention to the psychological needs of the users, their personality and the most important factors that are motivating them (Dalmina et al., 2019; Dempster et al., 2016), as well as considering the educational objectives and the desired results of the process (Alexe et al., 2013). Moreover, since the play-based learning experience has a dynamic nature with interactions between play, psychological, social, and pedagogical aspects, isolating specific game elements to evaluate the effectiveness of gamification may not result in the desired outcomes (Aldemir et al., 2018).

Several empirical researches conducted on the subject have shown how the use of gamification in the classroom can lead to a development of intrinsic and extrinsic motivation, the latter thanks to the use of elements that act as a reward, such as badges and progress bars (Rigby and Ryan, 2011; Groh, 2012), which promote and influence individual's innate desire for competition, success, recognition, and personal expression, as well as autonomy and competence (Kapp, 2012).

From an analysis of several empirical studies (Majuri et al., 2018), it emerged that applications of gamification in education most commonly use achievements and progression elements, while immersion ones are much less common. Nonetheless, in a recent exploratory qualitative study on subjective perceptions of the typical elements of gamification in learning contexts (Aldemir et al., 2018), the authors went beyond studying the most used 'PBL' triad and argued that a well-designed and correctly used gamification, applied to the educational field, has the potential to improve learning. Based on their findings, participants' opinions were merged into nine categories of necessary game elements, namely:

1. *challenge*, that allows involvement and is perceived both as a reinforcement for the content to be learned and as a self-evaluation strategy; it should be increasingly difficult and various, and both time and frequency in which it is proposed must be properly calibrated in order to maintain the 'flow state' (Csikszentmihalyi, 1996) — the flow state can be defined as the fully immersed mental state in which an individual performs an activity while enjoying it. When used in group settings, such as in the classroom, it allows to create a competitive collaborative environment and to balance group skills;
2. *narrative*, that stimulates players' immersion and empathy, besides giving coherency to all other elements. It must be relevant to the content, with respect to students' knowledge or interests. It is conveyed through a narrated communication and guiding characters, who tell the story and elicit the desire to follow its development;
3. *leaderboards*, even though they could generate a competitive environment, they increase participation and allow the creation of a reputation within the group;
4. *rewards*, extrinsic motivators (Deci and Ryan, 2000) which increase participation and, when obtained, are seen as a privilege compared to other players. They should be given continuously and systematically in order to avoid disengagement;
5. *badges*, as feedback and confidence boosters that can help players in their periodic self-assessment. They must be given in a continuous and systematic way and should be differentiated in levels to give more personalised feedback;
6. *teams*, to support community building processes and interactions among players. Within the classroom, teams could be created through the arrangement of students' seating, for example;
7. *win-state*, it is considered a good motivator, as long as it is objective and fair, remembering that if there is a winner, there is also a loser, but this can be prevented by providing more winners for different activities;
8. *points*, that, similarly to badges, are a form of feedback and, to have a positive impact, should be based on equity and on objective assessments;
9. *constraints*, they delimit the gamified context and offer a structure that students and players cannot exceed.

As for feedback, it is one of the most effective and most studied elements in gamification research. Defined as the action of returning the effect on the cause that produced it, with consequent modification of the principle that activated the process (Galimberti, 2018), feedback acts through associative learning, increasing the probability of obtaining a desired behaviour, whether the reinforcement is positive, or decreasing it, if it is negative (Skinner, 1963). This process affects both motivation and learning in general. Within games systems, feedback represents a crucial aspect, and indeed a core consideration of gamification research is how reward activities and, more importantly, how to provide meaningful and relevant feedback in relation to such activities.

Within a gamified system, feedback gives the user an understanding of their achievements and progress, and this can be obtained simply with a message (i.e., "Bravo, that's right!") or through a more complex system with points and badges. Regardless of type, feedback helps the user feel that they have achieved

something, either positive or negative. Negative feedback has been shown to reduce players' sense of competence, but motivate them to improve their poor performance and, therefore, incentivise short-term play. Whereas positive feedback satisfies the needs for competence and autonomy, thus raising intrinsic motivation and fostering long-term play (Burgers et al., 2015).
Furthermore, in relation to verbal feedback, it has been shown how evaluative feedback, that is the feedback that adds a level of judgment to an individual's performance, incentivises future game sessions, while comparative feedback, which provides social comparison by relating performance. with those of other participants, reduces such possibility (Burgers et al., 2015). Generic, and not necessarily personalised, feedback, however, can have positive effects on participants (Welbers et al., 2019).
While using video games within the educational context, feedback can also be automatic or given by the tutor or peers (Trinchero, 2014). The first type refers to the strategies of error management present within the game system, and is thus expected; after a committed mistake, it is possible to start again without any consequence, but rather having learned something new. Such feedback is usually immediate, structured, personalised, adaptive, and less influential on self-esteem than the feedback provided by a human tutor. The latter type, on the other hand, refers to situations in which an individual, that is an educator, teacher, parent, or a peer, plays with the student and helps them with the game challenge. The main purpose is to make the student progressively autonomous in regulating their own learning. This also allows the development and improvement of students' metacognitive abilities, and it is essential to ensure that the gaming experience becomes a learning occasion.
As confirmed by other studies, the role of the adult in the so-called 'guided play' — which differs from the game freely chosen by the child, that may have no didactic purpose, but also from direct teaching, during which the child tends to being passive and distracted — is essential (Weisberg et al., 2013). Although the activity remains focused on the child, the game is introduced and solicited by the adult, who can set different educational objectives, guide the activity through questions or comments, or by actively participating in the game, and monitor the child's progress, nonetheless letting them to perceive that the results depend on their own effort, so that they can improve their sense of self-efficacy.
In conclusion, it can be said that the use of feedback can increase students' motivation and improve their results, but to ensure its effectiveness, it must be relevant, in time, and meaningful (Domínguez et al., 2013).

1.8 Potential, limits, and risks of gamification

Although we are witnessing a rapidly growing number of applications field and an increasing research — as professionals from different study fields have been attracted by the potential of gamification to increase motivation and commitment in a wide range of activities, thus leading to the use of this strategy in sectors such as corporate resource planning (Alcivar and Abad, 2016), communication and intra-organisational activities (Thom et al., 2012), government services and public employment (Hassan and Hamari, 2019), health (Alahäivälä and Oinas-Kukkonen, 2016), social behaviour (Lee et al., 2013), marketing and advertising (Xi and Hamari 2019) — not only the definitions of gamification are dissimilar, but also the methodological aspect presents some limitations (i.e., sample sizes, measurement instruments, use of controls, etc.) and studies mainly advance without a theoretical guidance, leading to mixed and ambivalent results,
Some authors (van Roy and Zaman, 2019) hypothesise that this ambivalence is due to the influence of situational and contextual factors. In fact, similar gamification implementations in different domains do not necessarily have the same impact on users (Hamari and Tuunanen, 2014). In particular, demographic

variables and expectations have a different influence on the effectiveness of gamification features (Seaborn and Fels, 2015), and it is likely that the motivational experiences elicited by gamification may vary from individual to individual and have different significant effects (Huotari and Hamari, 2012; Dalmina et al., 2019).

One relevant concern about studies focusing on the correlation between gamification and the satisfaction of intrinsic needs is the lack of empirical evidence on how different gamification affordances, or the qualities of an object allowing the interaction with it, satisfy specific needs. Only few studies in literature examined the effects of one element at a time, making it difficult to estimate the effect of single affordances.

Among the most recent studies examining the effects of single elements on intrinsic need satisfaction, can be mentioned the research of Sailer and colleagues (Sailer et al., 2017), van Roy's and Zaman's work (van Roy and Zaman, 2019), and Xi's and Hamari's study (Xi and Hamari, 2019).

Sailer and colleagues (Sailer et al., 2017) presented a randomised controlled simulation study in order to better assess, through a subsequent questionnaire, how and to what degree different affordances, grouped in varying configurations, affect specific intrinsic needs. What emerged from the study is that different design elements address specific psychological needs, in particular the configuration with badges, leaderboards and performance graphs positively affected competence and perceived task meaningfulness, whereas the group with avatars, stories and teammates had a positive effect on social relatedness, but not on the perceived meaningfulness of tasks; crucially and surprisingly, the aspect of autonomy, or "perceived decision freedom", as it is called by the authors, could not be affected by any group, suggesting that certain gamification aspects are not effective per se, but strongly depends on the correlation of other affordances and on the context.

van Roy and Zaman (van Roy and Zaman, 2019) conducted a qualitative non-controlled analysis of surveys and focus groups interviews, gained throughout a University master course in which a small number of students used a gamified online platform with three different types of game elements: not-obligatory periodic challenges, in order to satisfy autonomy and competence needs; non-announced badges as positive feedback for both the need of autonomy and competence; and group competition, expressed by a leaderboards, to foster collaboration within groups and social interaction. The case study resulted in ambivalent outcomes. Students, indeed, reported feeling generally autonomous, competent, and related, but specific game elements, supporting one targeted need, hindered non-targeted ones (i.e., group competition, designed to support relatedness, diminished feelings of autonomy and competence), thus resulting in a loss of motivation and in the risk of frustration.

More interestingly, the work of Xi and Hamari (Xi and Hamari, 2019) investigated, through a survey-based study, the interaction between several gamification affordances, reflecting the three primary categories of game design elements (immersion, achievement, and social-related features) and intrinsic need satisfaction, according to SDT, in the large Xiaomi and Huawei online gamified communities. Immersion-related features (i.e., avatar, storytelling, customisation, etc.) have the principal purpose to immerse and engage the player in self-directed and customised activities, thus reinforcing autonomy feelings; challenges and achievements help players to set goals, receive feedbacks and develop their skills, thus enhancing their sense of competence; social-related features (i.e., groups, messages, link to social networks, etc.) reinforce interpersonal relationships and social participation. The results of the study show a substantial positive effect on intrinsic motivation; in particular:

- immersion positively influenced autonomy;
- achievements were positively associated with all needs and also were the strongest predictor of both autonomy and competence;

- social features also positively influenced all needs — and, most importantly, gave an important holistic contribution to the research about gamification, motivation, and intrinsic need satisfaction.

A secondary literature systematic review (Hyrynsalmi et al., 2017) states that there are negative aspects found in gamification research, to which particular attention must be paid. These can be grouped into two categories: limiting problems, i.e., due to the absence of better results, and harmful issues, i.e., the negative impacts of gamification, for example regarding user behaviour. The former mainly consist of observations that are related to an unsuccessful implementation of gamified functionalities, thus limiting the user to achieve the potential results that such experience could offer. Harmful issues, on the other hand, are mainly linked to questionable and potentially unethical side effects of gamification features, such in gambling and game addictions. The main difference between the two groups is that the limiting problems can be generally solved more easily than those belonging to the harmful category, which have more negative psychological repercussions.

In their study, Hanus and Fox (Hanus and Fox, 2015) analysed students' social comparison, effort, empowerment, satisfaction, motivation, and academic performance across two courses, one gamified and one traditional. They considered gamification elements that literature showed to be the most widely used, but that could also be problematic, and that are incentives, badges, and leaderboards. Results aligned with existing literature on rewards have negative effects on motivation, as students in the gamified course showed, over time, less intrinsic motivation, satisfaction, and empowerment, which eventually led to lower scores at the final exam. The study presents, though, some limitations. First, the students were forced to earn badges during course activities, which could have hindered their need for autonomy, thus decreasing their general intrinsic motivation. Second, the analysed affordances all belong to the achievement category only, according to Xi's and Hamari's classification (Xi and Hamari, 2019), and therefore not all the intrinsic needs may have been addressed and satisfied.

Narrowing the field to educational research, the results derived from gamification application have proved predominantly positive, with an increase in motivation, commitment, and fun (Lee et al., 2013), as well as in performance in various didactic activities (Faiella and Ricciardi, 2015). In their literature review, Koivisto and Hamari (Koivisto and Hamari, 2019) found that 35.7% of examined controlled experimental quantitative studies about *gamification* in this area resulted in fully positive findings; 32.1% of studies had mixed but mostly positive results; 25.0% had null or equally positive and negative results; and, lastly, only 7.2% of studies showed negative, or mixed with negative, results. This suggests a clear majority of positive findings in research, yet in another previous review, the two authors (Majuri et al., 2018) also reported that gamification studies in the educational context predominantly focus on quantifiable learning outcomes (i.e., grades and test results) when compared to research in other settings, more concentrated on motivational outcomes.

The ludic-educational design should not only have the aim to improve learning outcomes, but also to offer students effective, fun, and engaging activities and experiences (Quinn, 2005; Kiili and Lainema, 2008), starting from the basic elements of games and taking into consideration all three needs of intrinsic motivation (Rigby and Ryan, 2011). It was, indeed, demonstrated that when students perform optimally, they become less likely to continue playing. This confirms the importance of ensuring that they are sufficiently challenged, or the games must be programmed with an increasing setting of difficulty in the activities (Welbers et al., 2019).

CHAPTER 2 – Specific Learning Disorders and development of reading and writing skills

2.1 Classification and diagnostic criteria

According to the DSM-5 (APA, 2014), Specific Learning Disorders (SLD) are classified as neurodevelopmental disorders of reading, written expression, and calculation, characterised by the presence of a deficit that causes impairment of learning and of personal, social, and/or occupational functioning. The term 'neurodevelopment' highlights how the biological component affects cognitive abilities and behaviour and, at the same time, allows to differentiate an atypical development from a typical one. In the ICD-10 (WHO, 2007), SLD are included within the psychological development disorders with the term Specific Disorders of School Skills (specific disorders of reading, spelling, arithmetic skills, and mixed specific disorder, identified with code F81) for which the normal methods of acquiring skills are compromised starting from the initial stages of development. Furthermore, it is specified that these disorders are not due to a lack of opportunities to learn, do not derive from mental retardation and are not due to forms of brain trauma or acquired brain disease. Rather, it is believed that the disorders derive from abnormalities in cognitive processing linked, to a significant extent, to some type of biological dysfunction.
In the diagnostic report, each disorder is expressed with a code. Table 4 illustrates the distinct types of SLD with the respective codes of the DSM-5 and ICD-10.

Table 4. Correspondence between DSM-5 and ICD-10 classifications

DSM-5		ICD-10	
315.00	Specific Learning Disorder with impairment in reading	F81.0	Specific reading disorder (word reading accuracy, reading rate or fluency, reading comprehension)
315.2	Specific Learning Disorder with impairment in written expression	F81.1	Specific spelling disorder (spelling accuracy, grammar and punctuation accuracy, clarity, or organization of written expression)
315.1	Specific Learning Disorder with impairment in mathematics	F81.2	Mathematics disorder (number sense, memorization of arithmetic facts, accurate or fluent calculation, accurate math reasoning)
		F81.3	Mixed disorder of scholastic skills
		F81.8	Other developmental disorders of scholastic skills

		F81.9	Developmental disorder of scholastic skills, unspecified

Certain basic criteria must be met for the diagnosis of all specific developmental disorders of scholastic skills (Istituto Superiore di Sanità – SNLG, 2010).

Criterion A. At least one of the symptoms must be present (inaccurate or slow: reading, understanding the meaning of what is being read, spelling, written expression, mastering the concept of number, numerical data or calculation, mathematical reasoning) for a period of at least six months, despite targeted interventions on these difficulties.

Criterion B. Individual's performance in scholastic skills appears to be below the average for age, or acceptable levels are achieved but only with significant effort. Therefore, there is a strong interference with school or occupational performance, but also with the activities of daily life. This criterion requires psychometric evidence from a series of standardised tests. In Italy, the Consensus Conference on Learning Disabilities (Istituto Superiore di Sanità – SNLG, 2010) takes into consideration the international criteria and carries them further towards the development of a dimensional approach to psychological diagnosis.

Criterion C. Individuals with SLD present such difficulties throughout their life, in activities that involve the use of the impaired skills, and this permanent condition is, in general, resistant to treatment.

Criterion D. Impairments occur in individuals with an average IQ and the difficulty cannot be attributed to other deficits, such as intellectual disabilities, sensory problems, psychosocial disadvantage conditions or a more general developmental delay.

However, the disorders have a course that can change longitudinally over time, as the manifestation of symptoms can have significant changes due to development, interventions and environmental conditions that interact with neurobiological factors.

The DSM-5 (APA, 2014) also introduced three levels of severity of SLD, depending on the level of impairment:

- *mild*, intended as the need for a simple adaptation of teaching for the student, who may present difficulties in learning but may be able to compensate independently;
- *moderate*, the most frequent condition with marked difficulties which, making it unlikely that the individual can reach an adequate level of skill without periods of intensive teaching, require help or support (e.g., with dispensative/compensatory tools, cognitive enhancement, etc.);
- *severe*, in which there are obvious difficulties that negatively affect learning and that make it unlikely that the student can reach an adequate level of skill without individualised teaching. Although dispensative or compensatory tools are used and the student is helped appropriately, it is possible that they may not be able to complete all school activities efficiently.

2.2 Developmental Dyslexia

Developmental Dyslexia, or specific reading disorder, is the most significant example of SLD. The main feature of this disorder is a specific and significant impairment in the development of reading skills, which is not explained solely by mental age, visual acuity problems or inadequate school education. An individual can, therefore, be diagnosed with Developmental Dyslexia when there is a discrepancy between cognitive skills, which appear to be normal, and reading performance without an apparent physical, emotional, or cultural cause.

The diagnosis cannot be formulated before the end of the second year of primary school, even if it is possible to formulate a diagnostic hypothesis as early as the end of the first year of primary school for those children who show very compromised functioning profiles and in the presence of risk indicators, such as important signs of discrepancy between general cognitive skills and the learning of reading and writing (Stella, 1996). The essential parameters for the diagnosis, in transparent verbal systems, such as the Italian language, are the speed measured as reading time of texts, words or syllables, and the accuracy measured as the number of reading errors. Understanding the text does not contribute to formulating the diagnosis of Developmental Dyslexia, even if it provides useful information on the efficiency of the reader (Cornoldi, 2019; Ferraboschi and Meini, 1993; Stella, 1996; Tressoldi and Vio, 1996).

In order to assess reading ability, several sources of information must be used, one of which involves the individual administration of "culturally" and psychometrically appropriate reading tests. The professional has thus to provide:

- the administration of adequately standardised reading tests at multiple levels: words, non-words, and texts;
- the joint assessment of the speed index and the decoding accuracy index of the performance;
- the detection, in at least one of the indices (speed and/or accuracy), of a significant distance of the results from the average values expected for the class attended by the child. This difference is conventionally set at -2 standard deviations from the mean for speed, and below the fifth percentile for accuracy.

Developmental Dyslexia is also due to an individual's biological predisposition. Studies have shown the familiarity of the disorder, that is, a higher probability in children from families where other individuals have the same disorder (Paulesu et al., 1996; Facoetti et al., 2000). The reference to a biological predisposition does not imply that the condition of dyslexia cannot be improved through specific activities and practice, and through the creation of a suitable help network.

2.3 Developmental Dysorthography

Developmental Dysorthography is a deficit in the processes of spelling, with specific and significant impairment of the development of spelling and coding skills of the word, thought or heard, in the corresponding written form, following the rules characterising the origin language. This, in the absence of a history of specific reading disorder and reduced mental age, visual acuity problems or inadequate school education (WHO, 2007). Skills related to correctly spelling and transcribing words are both affected. Unlike what is usually observed in specific reading disorders, spelling errors tend not to concern the phonetic aspect.

The DSM-5 (APA, 2014) differentiates between accuracy in spelling, accuracy in grammar and punctuation, and clarity and organisation of the written expression. Specifically, the writing disorder can affect various levels of competence:

- the orthographic component (dysorthography);
- the motor component (dysgraphia);
- the component of the written expression (creation of sentences and texts).

The analysis of the writing process requires the assessment of the dysorthographic and dysgraphic components. For the diagnosis of Developmental Dysorthography, the child's performance, in terms of quantity of spelling errors, has to be two or more standard deviations below the average of children attending the same school grade; on the other hand, dysgraphia seems to be a consequence of dyspraxic motor performance disorders, when it is not part of a spastic or ataxic or extrapyramidal diagnosis (Cornoldi et al., 1999; Ferraboschi and Meini, 1992; Martini, 1998).

2.4 Aetiology: theoretical models

At the base of Developmental Dyslexia and Dysorthography, and, in general, of SLD, intervene neurobiological dysfunctions, or disorders interfering with the normal process of acquiring scholastic skills, and environmental dysfunctions, or the interaction with school, family and social environment, determining the phenotype of the disorder and a greater or minor maladaptation of the individual. Even though considerable effort has been expended to define the possible cause of such SLD, no single answer has been agreed upon.

Since the 1970s, neurodevelopmental disorders have been explained and interpreted within a single cognitive deficit perspective. More recently, however, the multifactorial neuropsychological hypotheses prevailed, supporting the fact that every single developmental disorder is the result of the interaction between multiple factors (Cornoldi, 2019).

2.4.1 *Uta Frith's developmental framework of reading and writing*

According to the model proposed by Uta Frith (Frith, 1986), the development of reading and writing skills involves a sequence of four chronological stages (Fig. 5), dependent on each other, in which both biological and cultural factors interact and characterised by different strategies and skills.

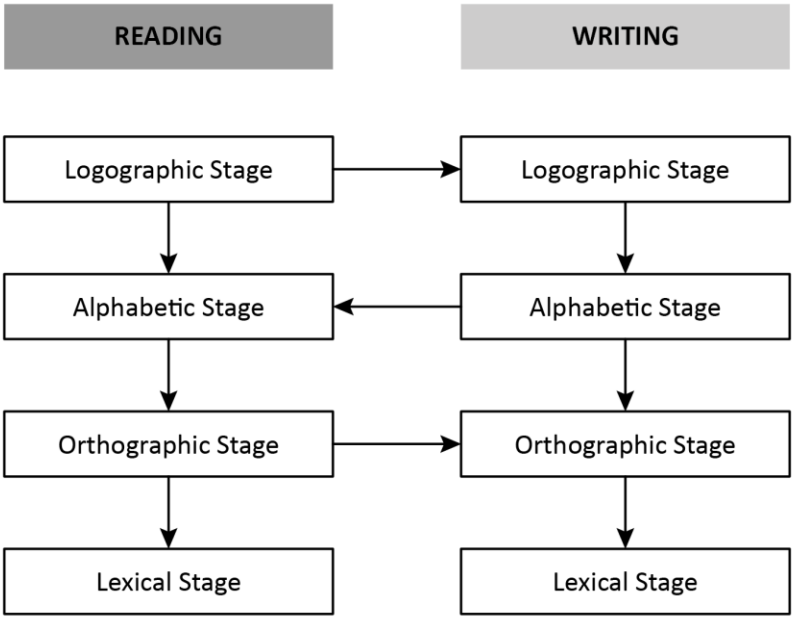

Figure 5. Frith's developmental framework (1986), integrated by subsequent studies (Marshall, 1984)

Logographic stage (5-6 years). Children can recognise that a certain word refers to a certain thing, even if they do not yet know the individual sounds. Within this stage, two skills are developed: phonological awareness, that is the ability to recognise the phonemic parts of a word and to manipulate its phonological segments, and visual skills, that is the ability to recognise the visual components of a word. At this stage, the order of the letters is largely ignored, and the phonology is recovered only after the word has been identified. The child is unable to respond to unfamiliar words presented in isolation and uses contextual and pragmatic clues to guess unfamiliar words encountered in a context. Furthermore, the child writes the words as if they were ideograms or drawings; even the ability to write their own names is not based on knowledge of the grapheme-phoneme relationship, but on the visual form of the sequence of letters.
Alphabetic stage (6-7 years). Children acquire the ability to convert the grapheme into the corresponding phoneme (phonological reading), thus allowing them to read unknown, new, and non-words, and the phoneme-grapheme conversion mechanism for writing. The approach to writing and reading is no longer global, but becomes a systematic approach, with a primary role attributed to phonology and the order of letters. In the Dual-Route Cascaded (DRC) model of Coltheart and colleagues (Coltheart et al., 2001), the grapheme-phoneme conversion mechanism corresponds to the sublexical route. This process implies that the child can segment the string of letters, assign the correct sound (phoneme) to each grapheme and, by joining the broken-down parts, read the entire word. In the writing process, the reverse occurs, and, in the DRC model, this phase corresponds to the phonological route.
Orthographic stage (8+ years). Children learn the spelling rules of their native language, the peculiarities of words and the recursive form of consonants and vowels within words and acquire lexical reading skills. The child learns to recognise and apply the phoneme-grapheme conversion rules to parts of the word: syllables, morphemes, etc. It is the phase that allows the analysis of words in orthographic units, with reference to morphological factors and to take parts of words together without having to do a segmental analysis, which makes both writing and reading faster. According to the DRC model (Coltheart et al., 2001), this phase, which serves to economise the recognition process and to memorise language exceptions, corresponds to the lexical route.

Lexical stage. Children learn to recognize and write words globally, without applying the phoneme-grapheme conversion rules. It is the phase that allows the direct reading and writing of the word, without going through a phonological recoding of its parts. The word is written by recovering its orthographic form from the specific lexicon in which it is stored. The highest stage is reached gradually, in relation to the frequency of use of the word and its linguistic complexity. This phase corresponds, in the model of Coltheart and collaborators (Coltheart et al., 2001), to the semantic-lexical route.
With explicit reference to Frith's developmental model (Frith, 1986), Seymour (Marshall, 1984) argues that writing in the alphabetic phase (stage 2) helps the development of reading, while the orthographic phase of reading (stage 3) would help the development of the orthographic writing.

2.4.2 *The Dual-Route Cascaded model*

The studies concerning the difficulties of reading and writing (in its orthographic component) generally take as theoretical reference the Dual-Route Cascaded (DRC) model (Coltheart et al., 1987), reported in Fig. 6.

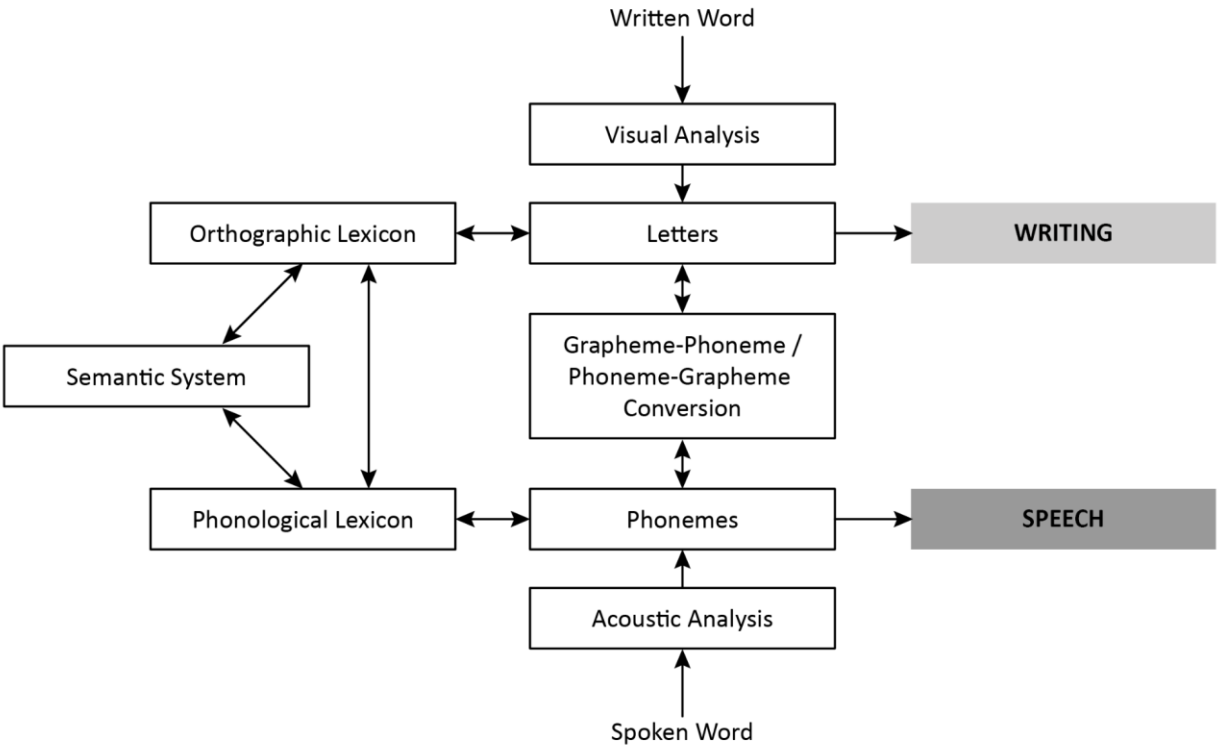

Figure 6. Dual-Route Cascaded model of reading and writing (based on Coltheart et al., 1987)

As regards reading, the model, which has been effectively simplified by Cornoldi (Cornoldi, 2007) (Fig. 7), involves a phonological route that passes through the application of the transformation rules between spelling and phonology, and a lexical or direct route given by recognition of the word as a unit, which would activate both the meaning and the phonological representation typical of the spoken language.

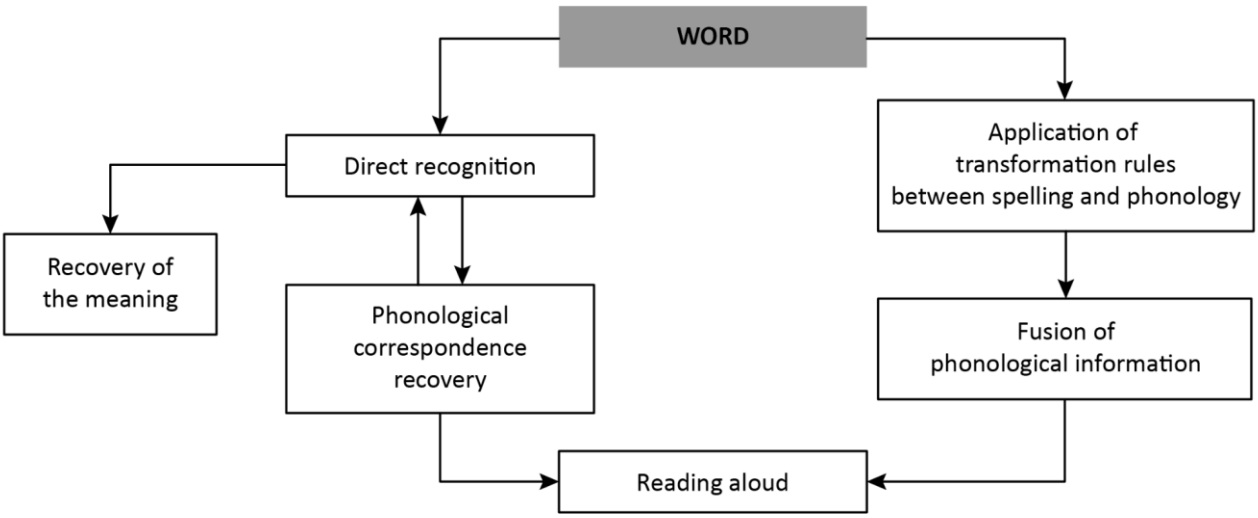

Figure 7. Simplification of the DRC reading model (based on Cornoldi, 2007)

According to the model, the cognitive processes that allow the decoding of the word, that is the ability to analyse what is on a page and recognise that they are graphemes, can activate two different routes: the sub lexical, or prelessical phonological, route, and the lexical, or semantic visual, route.
The sublexical way proceeds from the identification of the letters to the connection with their sound, through a grapheme-phoneme conversion mechanism, and reaches the semantic system through auditory recognition. An impairment in this route determines the so-called 'phonological dyslexia', characterised by errors in reading, slowness in recovering the pronunciation of the grapheme or syllable (Marshall, 1984).
The lexical route, on the other hand, allows immediate recognition of the written word. Through the visual input, this route allows quick access to the semantic system, a dictionary present within the long-term memory and containing the meanings of the words, and, therefore, to understand the written text. This is the mode used by most experienced readers, who can quickly understand what they are reading. An impairment in this route determines 'surface dyslexia', characterised by errors in reading irregular words and confusion for non-homograph homophones (Marshall, 1984).
Furthermore, reading aloud involves the output phonological lexicon, which transforms the written word into a representation of sound, and the articulatory system, which allows the pronunciation of the word. An impairment that concerns the semantic processing in combination with a phonological damage, that is a difficulty in both lexical and sublexical routes, produces 'deep dyslexia', characterised by errors in reading both words and non-words (Marshall, 1984).
In addition to the already mentioned central ones, based on the DRC model it is possible to hypothesise some forms of peripheral dyslexia. These types are due to an impairment at the attentional or perceptual level of processing the stimulus. 'Attentional dyslexia' (Friedmann and Haddad-Hanna, 2014) involves a reduced ability to be able to ignore the surrounding irrelevant stimuli and the letters migrate between neighbouring words. The 'letter position dyslexia' (Friedmann and Rahamim, 2007) and the 'letter identity dyslexia' (Brunsdon et al., 2006) are both due to an impairment in the visual-orthographic analysis system; the former leads to errors in the position of the letters, while the latter does not allow access to the abstract identity of the letters starting from their visual form. There are also 'neglect dyslexia' (Friedmann and Haddad-Hanna, 2014), in which there is a selective attention on a specific part of the word, typically the left, due to right impairment, and 'visual dyslexia' (Marshall and Newcombe, 1973), caused by dysfunctions in all sub-components of the visual-spelling analysis system, which causes the target word

to be read as a visually similar word, with substitution errors, omissions, migrations and additions of letters.
Also writing can be interpreted according to the DRC model, but in this case a reverse process takes place (Cornoldi, 2019). The two routes that are followed during writing are the phonological route and the semantic-lexical route, which have different developments but are intertwined and mutually influence each other (Fig. 8).

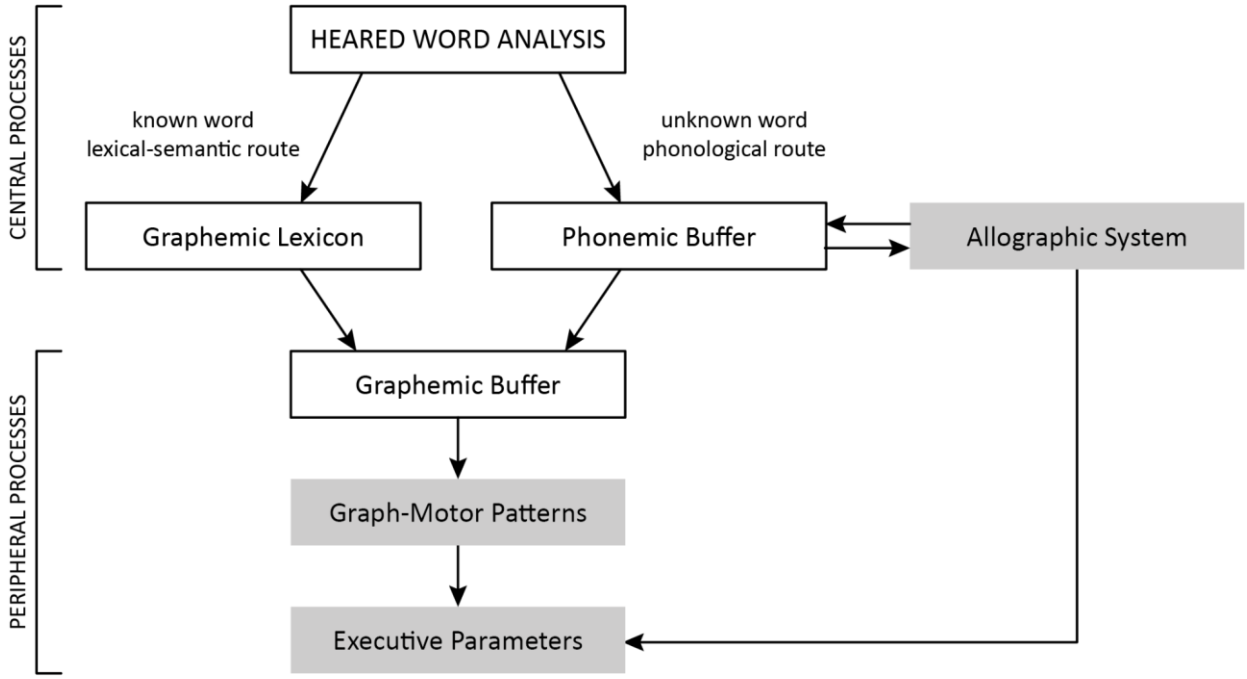

Figure 8. DRC writing model (based on Cornoldi, 2019)

In the phonological route, the process starts from the acoustic analysis of the auditory input and arrives at the composition of the word on paper using a specific writing method (allographic system), only after each phoneme has been matched with a specific grapheme (phonemic buffer). This allows reconstructing the orthographic structure of the word through an assembling process of the individual graphemic segments through the application of phoneme-grapheme conversion rules. It is useful in transcribing unknown words.
In the semantic-lexical route, on the other hand, following the acoustic analysis of the auditory input, the writing of the word takes place after it has been recognized in the semantic system (graphemic lexicon), which allows the understanding of the meaning of what is heard and the recovery of the entire word orthographic form. It is used in writing known words and in the transcription of words with ambiguous spelling and homophonic non-homographic forms.
Subsequently, both routes converge in the graphemic buffer, which has the task of storing the graphemes and their correct position in memory for all the time necessary for writing. Subsequently, more peripheral processes are activated, i.e., graph-motor patterns, for the programming of graphic response. Visual-perceptual, motor, and visual-spatial skills are also used in these processes.

2.4.3 *Multifactorial model*

Recently, the conceptualisation of SLD has undergone substantial changes. Even if the existence of a phonological core deficit is almost universally recognised and accepted, it is no longer considered as a sufficient cause to fully explain the multiplicity of manifestations and causal factors underlying SLD (Kibby et al., 2014). Most researchers are moving towards a probabilistic and multifactorial perspective (McGrath et al., 2010; Menghini et al., 2010; Pennington, 2006; Pennington et al., 2012), by which it is recognised the natural complexity of the neuro-functional system and of the various interconnected levels of organisation to which this complex system adapts during the development and acquisition of skills.
The Multiple Deficit Model (Pennington, 2006) proposes that the aetiology of complex behavioural disorders is multifactorial and involves the interaction between multiple risk and protective factors, which can be both genetic and environmental. Such factors alter the development of cognitive functions necessary for neurotypical development, producing behavioural symptoms that define developmental disorders. Thus, no single aetiological factor is sufficient for the development of one disorder, but several are needed and comorbidity between complex behavioural disorders can be present because they can share aetiological and cognitive risk factors. The distribution of responsibility for a certain disorder is, indeed, often continuous, and quantitative, rather than being discrete and categorical, so the threshold for having a disorder is somewhat arbitrary.
The multifactorial model therefore provides for the interaction between the following four levels of analysis:

1. aetiological risks and protective factors;
2. neuronal systems;
3. cognitive processes;
4. symptoms.

Therefore, each disorder can be caused by a concurrence of factors, and these can be present in multiple disorders. This is supported by the existence, for example, of different forms of dyslexia and its frequent comorbidity with other neurodevelopmental disorders, such as those of language or attention (Pennington, 2006).
It is important to note that this multifactorial perspective is not antithetical to that of cognitive neuropsychology, which proposed, with the DRC model (Coltheart et al., 1987), a hypothesis of functional architecture of reading and writing processes that involves a coherent and interconnected system of specialised computing components at distinct levels. In this sense, two different research traditions, both engaged from different perspectives in the study of SLD, seem to have found a critical point of convergence.

2.5 Assessment and intervention

The recognition of the heterogeneity, with which Developmental Dyslexia and Dysorthography typically manifest themselves in different subjects and in the different evolutionary phases of skill acquisition, suggests the possibility that different factors may be at work in determining the expression of the disorders both between different subjects, and for the same individual at different moments of their development. At the rehabilitation level, this implies that different individuals may have unique needs, just as the same person may manifest different difficulties and rehabilitation needs during the stages of development and the progressive acquisition of reading and writing skills.

In order to plan a good and effective intervention, to reduce the symptomatology of the disorder and improve the general condition of the individual, it is necessary to have a complete knowledge of their clinical picture. This implies not only knowing their overall cognitive functioning, with strengths and weaknesses, but also their psychological and emotional state in relation to the context.
A treatment is defined as effective when it can produce a greater change than is possible in absence of an intervention, and when is combined with series of factors:

- severity and pervasiveness of the disorder - how much the specific ability is damaged and, therefore, performance is compromised, with respect to subjects of the same age and with comparable educational opportunities, and to the amount of emotional-relational aspects involved. The efficacy of the intervention is, indeed, linked not only to the characteristics of the disorder, but also to the cognitive potential, to the relational and family context, and to the possibility of implementing support strategies;
- motivation - the contribution of the individual to the rehabilitation program is also important, A good awareness of one's difficulties and a clear understanding of the causes of the disorder can promote a positive attitude towards treatment and the motivation to learn;
- duration - it is specific for each type of disorder and there are often situations in which a lot of time and resources must be involved before seeing improvements. However, it is important that the patient is aware about the type of intervention and the timing required;
- network of resources - it indicates the amount of collaboration that can be obtained from the involvement of other specialists, reference figures in the family and relational context (i.e., teachers, parents, and peers).

Therefore, there cannot be a single rehabilitation program that is effective for each individual case, rather the intervention should be adapted according to the peculiar characteristics of the clinical-functional picture of each subject, highlighted through careful and detailed neuropsychological evaluation.

2.5.1 *Interventions for Developmental Dyslexia*

Much of the rehabilitation interventions for Developmental Dyslexia are based on reading re-education strategies that involve the manipulation of letters and sounds to increase phonological awareness, and exercises in word analysis, comprehension and reading of a text with increasing difficulty to improve fluency. In general, accuracy difficulties are easier to treat than fluency, which depends on the amount of reading practice. In addition to a careful choice of exercises, the intervention program should be structured to stimulate the attention of the individual, as vigilance and reward systems regulate the degree of learning.
It is possible to improve speed and accuracy of reading by focusing on four basic aspects (Tressoldi and Vio, 2012):

- visual discrimination and visual-spatial selection, as in reading it is necessary to proceed with a visual analysis of the visual characteristics of the stimulus;
- denomination of graphemes, i.e., each phoneme must be assigned to the corresponding grapheme;
- automation of recognition of sublexical units and whole words;
- phonemic fusion, starting from phonemic synthesis, that is the ability to keep a series of phonemes or syllables in the short-term phonological memory until they are merged to obtain a whole word.

For transparent languages, interventions that offer quick reading of whole words or facilities the identification of syllables, are considered effective (Istituto Superiore di Sanità – SNLG, 2010). In general,

it is recommended to structure rehabilitation cycles, even short, but repeated over time, in two or three sessions a week for at least three months. In addition, the most effective interventions are those initially aimed at maximum correctness in reading words and, subsequently, aimed at increasing the speed in syllables and words recognition (Tressoldi et al., 2007; S. Cazzaniga et al., 2005).

The central and crucial stage in learning to read is the alphabetic one, as confirmed by many authors (Adams and Bruck, 1993; Wimmer, 1993). In this phase, subjects acquire and automate the recognition of ever larger parts of the written word. Initially, the reader focuses on each single grapheme but, almost simultaneously, they begin to refer to groups of letters corresponding to syllables, prefixes and suffixes, morphemes.

Less complete, however, is the knowledge of the lexical stage development and its relationship with the development of the previous one. The data that are emerging for the English language indicate that individuals gradually learn the relationship between phonological and orthographic representation at various levels: single letters, groups of graphemes corresponding to sub-syllabic, syllabic, and morphemic components, up to form a specific association to the whole word level. Readers acquire a multiplicity of connections, of which those at the sublexical level (letters, syllables, etc.) are used for the recognition of new and not yet fully recognised words, while those at the lexical level are for the recognition of irregular and already familiar words (Berninger et al., 1991; Carreiras et al., 1993; Perea et al., 2004; Tyler and Nagy, 1990). For the Italian language, normal readers already refer to morphemes in the reading process at the age of 8 (Burani et al., 2002). It is assumed that in the neurotypical reader, the evolution of the skills involved in instrumental reading (speed and accuracy) occurs spontaneously through the simple reading experience. It is therefore assumed that the perceptual system can detect groups of graphemes that have a psycholinguistic value by associating them with the verbal knowledge possessed by the reader by simple and prolonged exposure.

For all those who, on the contrary, do it with great difficulty, and therefore show a specific delay in speed and accuracy compared to their peers, it is assumed that the system is not adequately prepared for such function, due to normal biological variations of all cognitive functions and of the phonological ones. In other words, for subjects who show significant delays in learning to read not attributable to cortical lesions or to sensory and teaching deficiencies, it is hypothesised that at the base of the difficulty there is poor phonological competence (Lundberg and Høien, 1989; Rack et al., 1992; Yap and Van Der Leij, 1993). This structural inefficiency can be partially overcome: this is the hypothesis underlying sublexical interventions that operate by facilitating the cognitive processes involved in reading, in particular the detection of important sublexical parts, such as the syllable, up to the recognition of whole words, to associate them with phonological correspondences through prolonged repetition aiming at maximum speed and accuracy.

An analysis of the studies on the efficacy of interventions in Italy for Developmental Dyslexia (P. E. Tressoldi and C. Vio, 2011), compares sub lexical, lexical, neuropsychological and Balance Model treatments, taking into consideration the speed index, expressed in syllables per second in the reading of words, non-words, and texts, and of efficiency, that is the changes in speed per hour of treatment.

Results showed that sublexical treatment, which aims to automate the correct association between syllables and their phonological correspondences through tachistoscopic exposure or various perceptual facilitations, is the most effective; in particular, individuals showed significant improvements in reading speed without compromising accuracy, which reached several errors within the standard. As regards efficiency, improvements can be found in a fairly short time (at least 5-6 hours per month for 3-5 months) and the time window for potential recovery is not limited to the first years of primary school, meaning that improvement is independent of the patient's age and the initial severity level.

As for the lexical intervention, which is based on an association mechanism between words and their phonological representations, the results are conflicting as it seems to improve the reading speed only for stimuli that have been presented several times and, therefore, there would be no generalisation.
Neuropsychological interventions, aimed at enhancing cognitive skills transversal to reading (i.e., verbal memory, visual attention, sensory perception, etc.), produce a significant change in the measure of effectiveness after training. Instead, they show a lower efficiency index than other treatments as a longer period is required to observe some improvements.
Finally, the Balance Model refers to interventions involving different exercises and materials according to the patient's type of dyslexia, classified according to their own perceptual, linguistic, or mixed procedures. The sublexical treatments, with the presentation of onscreen text to be read with facilitations to highlight the syllables, and those based on the Balance Model (Bakker and Vinke, 1985), which require the reading of words presented tachistoscopically (time < 300 milliseconds) and directly exploits the access of words to the two cerebral hemispheres, obtained an average improvement of about 0.3 sill/sec, without compromising accuracy by increasing the reading speed, but rather reaching levels of correctness within the standards.
The use of technology is increasingly common in the various activities of daily life, and rehabilitation programs have also been influenced by it. During interventions, it is important to consider some elements that guarantee learning such as attention, motivation, and active interest. Technological progress would seem to have provided an interesting response to these needs, without losing clinical treatment objectives and carefulness. ICT knowledge, combined with psychological knowledge relating to reading skills, allowed the design of *ad hoc* software for the creation of exercise programs suitable for each user, ensuring their persistent involvement over time. From this point of view, the principles of gamification can be fundamental (see Chapter 1 and Chapter 2).

2.5.2 *Interventions for Developmental Dysorthography*

Writing involves decoding and placement operations that use conventional arbitrary graphic elements (letters), sequential and articulated in a linear form (Ajuriaguerra, 1979). It is an important cognitive skill whose execution requires the use and control of visual and phonological information processing, similarly to what happens for reading, but it also requires adequate programming of coordinate motor sequence execution.
Such ability, expressed at different levels of competence (from writing words to writing a text), involves a rather long learning process divided into stages, each of which involves the acquisition of cognitive and graphic-motor skills, more and more sophisticated. Throughout the process, the writing of the word, also known as the technical ability of writing, represents a particularly important intermediate stage. This ability is generally considered to have been achieved when the student is able to write under dictation while respecting the rules of the written language.
When considering the process of writing under dictation, it is therefore possible to hypothesise two main mechanisms of processing the auditory stimulus, namely:

1. the visual-lexical system for writing familiar words, able to uniquely specify the writing of words that are not totally transparent;
2. the phonological system of phoneme-grapheme conversion for the writing of words encountered for the first time or for the writing of non-words.

The DRC model (Coltheart et al., 1987) highlights how the crucial phase of any writing system based on alphabetic rules is, precisely, the alphabetic one, i.e., the stage in which children first recognise that the sound of a word can be broken down in smaller parts (first the syllables and then the phonemes) and,

subsequently, they associate them with the corresponding graphemes by applying the language transformation rules. Later, especially for less transparent reading and writing systems, such as English, children have to memorise the exceptions to these general rules. The orthographic stage, as already mentioned, is a phase of improvement and economisation of the alphabetical stage and is intermediate to the lexical one, as it serves both to learn the exceptions to the rule "one phoneme = a grapheme", and to reduce grapheme-phoneme transformation phases and make words recognition or writing faster.
From Frith's developmental framework (Frith, 1986) derives a classification of errors, developed, as regards the Italian language, by Tressoldi and Cornoldi (Tressoldi and Cornoldi, 1991):

- *phonological errors*, in which the relationship between phonemes and graphemes is not respected. It includes exchanges of graphemes ("dende" instead of "tende"); omission or addition of letters or syllables ("taolo" for "tavolo"); inversions ("li" for "il"); incorrect grapheme ("agi" instead of "aghi");
- *non-phonological or lexical errors*, concerning the orthographic representation of words without making mistakes in the relationship between phonemes and graphemes. It includes illegal separations ("in sieme" instead of "insieme"); illegal fusion ("lacqua" instead of "l'acqua"); exchange of homophone grapheme ("quore" instead of "cuore"); omission or addition of "H" in case the child has to decide whether it is the verb "to have" or a preposition ("o mangiato" instead of "ho mangiato");
- *other types of errors or phonetic errors*. It includes omission and addition of double consonants ("biscoto" instead of "biscotto"); omission and addition of accents ("perche" instead of "perché").

Insufficient acquisition of the alphabetic stage leads the child to make phonological errors, while insufficient acquisition in the spelling or lexical stage leads the child to make non-phonological errors.
Spelling accuracy requires to develop and enhance at least five components (Tressoldi and Vio, 2012):

1. memory and phonological discrimination, important for preserving and write thought or heard words;
2. phonemic analysis or segmentation, that is the ability to identify all the phonemes of the heard or thought word;
3. phoneme-grapheme association, or associating the phonemes, identified through phonemic analysis, with the related graphemes;
4. phonological-orthographic association for non-homographic homophonic words, that is the formation of orthographic representations of words which, despite having the same phonemes, are represented with a series of different graphemes or which are exceptions with respect to the grapheme-phoneme association rules;
5. writing praxis, concerning the fine motor skills of the dominant hand that allow to create the shape of graphemes in a legible and quick way.

At the moment, however, there would be no experimental interventions in regular spellings, such as Italian, to recommend in clinical application (Istituto Superiore di Sanità – SNLG, 2010). Instead, as regards non-transparent languages, a meta-analysis (Wanzek et al., 2006) identified as effective those interventions with explicit instructions, possibility to repeat exercises, and immediate feedback. The interventions conducted with the use of information technologies aimed at improving spelling have also proved effective.

2.6 Clinical advantages of a digital training

Information technology seems to provide multiple opportunities also in the management of rehabilitation exercises, including a more attractive work environment for the patient and precision in the presentation of stimuli that often require accurate timing of exposure and the ability to automatically and precisely record the answers provided.

Digital environments are not considered alternatives to the more traditional rehabilitation practice, mostly based on paper tools, but their intrinsic resources and potential try to overcome the main limitations of such tools by integrating them in a functional and efficient way. Moreover, the professional who uses digital tools remains fully responsible for the planning and management of the rehabilitation program. Therefore, digital tools aim to help professionals by providing, for example, updated and automatically managed reports of several patients at the same time, and giving the possibility to have an instant view of the entire intervention and to monitor progresses, with the possibility of modifying it based on precise data that report its effectiveness in objectives achieving.

Another major limitation of the rehabilitation activity can be constituted by the preparation of materials to be used during the session, which requires time to the professional, especially if the material must be prepared *ad hoc* for a specific patient. To assess this, standardised interventions are increasingly proposed, thus leading to grouping problems under the same nosographic label (i.e., 'dyslexia'), and treating them as a single entity, without recognising the diversity of functional profiles. Undeniably, such a rehabilitation strategy saves a lot of time, but at the cost of not specific interventions. Instead of adapting the intervention program to the specific needs of the child, it is the child who must adapt to the rehabilitation program, without considering the risks, especially in terms of motivation.

Moreover, materials should be updated to prevent the patient losing interest within a few sessions. Digital systems offer the opportunity to have many stimuli (words, texts, images, etc.) that can be used in randomised sequences, graded according to difficulty levels, thus avoiding repetition, and getting used to a standard sequence. The professional is nonetheless responsible for choosing the most suitable exercise parameters for that child, in that phase of the rehabilitation process.

Such adaptive features of digital systems are especially important on the motivational level (Besio et al., 1992; Pinnelli and Sorrentino, 2013) for the fact that, by avoiding the repetitiveness of the stimuli and setting the parameters on the basis of child's real abilities, it is possible to avoid getting used to a predefined and predictable pattern, which often ends up boring the child, and to keep motivation high in the perspective of a correct execution.

In addition to these advantages, digital tools and the Internet offer the possibility of remote rehabilitation (Aiello et al., 2013; Franceschi and Facci, 2013; Stella et al., 2011; Tucci et al., 2015). In fact, also due to the recent health emergency, the traditional rehabilitation setting, consisting of the one-to-one relationship in presence between patient and professional, is increasingly losing its characteristic of exclusivity in favour of other forms and modalities of intervention, less demanding on an economic and logistical-organizational level, but not necessarily less effective. In recent years, for example, the excessive costs of rehabilitation treatment have led numerous structures of the National Health Service (NHS) to reduce the provision of rehabilitation treatments and to carefully select beneficiaries based on eligibility or proven effectiveness criteria. Regarding the developmental age, Specific Learning Disorders (SLD) particularly suffered from this situation, both because they are considered of more limited clinical relevance than more serious disorders, and because the efficacy evidence of rehabilitative interventions for SLD remain rather scarce and limited, at least in Italy (Istituto Superiore di Sanità – SNLG, 2010). Therefore, interventions for SLD underwent a significant decline, even though an early treatment in these

cases, even if it is not resolutive of the disorder, can make a significant difference for the life quality of patients, from an educational, personal and social point of view (Lyon, 1998).
There are also various logistical aspects (distance, incompatibility of schedules, etc.) that can interfere with the quantity and quality of rehabilitation interventions, at times completely nullifying their effectiveness, at other times leading to premature abandonment of the planned program. In this perspective, digital tools and software for remote rehabilitation seem to offer an interesting opportunity and an adequate solution to many of these problems.
What cannot be replicated in remote rehabilitation is the relationship that is established between the child and the professional, an aspect that cannot be underestimated because in many cases the established therapeutic alliance constitutes the added value for rehabilitation effectiveness and determines its success or failure. Ideally, the parent or caregiver who takes care of the rehabilitation session at home could become a surrogate for the professional, but this could be more the exception than the rule. It is therefore necessary to be aware that this can constitute an important limitation of remote rehabilitation and requires preliminary context and case evaluations. Despite this, it is possible to explore the potential of a remote rehabilitation program, trying to develop the possibilities and flexibility offered by new information technologies to their best.
A further problem, always present when a rehabilitation program extends over time, is motivation. Usually, professionals dedicate an important part of their work precisely to trying to stimulate and preserve patients' motivation and engagement over time. Remote rehabilitation could be unable to fully address this problem (Pinnelli and Sorrentino, 2013) and the risk is that, after an initial enthusiasm for the new technology and for the possibility of doing rehabilitation at home, child's and parents' interest is exhausted, nullifying the usefulness of the program. Therefore, in order to prevent the possible motivational decline, which typically accompanies interventions, in addition to preliminarily working to the setting (space, times, methods, reinforcements, etc.) in which the remote rehabilitation takes place, it is possible to work on the type of tools to be used and, in this sense, gamification application has already shown potential (Tucci et al., 2015).
The interest in use of computerised educational strategies aimed at children and young people with Special Educational Needs (SEN) began starting from 2010. In the literature there are various research in which gamification is applied to different student populations, such as students with SLD or ADHD, intellectual disabilities, and language problems. In fact, there is a strong use of this methodology to support the most diversified learning styles of students, both within the school context and within rehabilitation centres (Börjesson et al., 2015).
Such interest increased significantly in recent years since most students with difficulties have a demotivated attitude towards school and the educational process. In addition, they show greater difficulties when learning to read, write and calculate, and often get bored easily and quickly lose interest in repetitive activities. Given the aforementioned evidence of how gamification is able to significantly increase motivation and students' involvement, Special Education has begun to integrate the use of technologies through mobile devices in the classroom. The use of gamified applications on tablets has shown a positive response from students with SEN and reported greater fun in the process of reading and writing learning (Ifigenia et al., 2018).
Furthermore, students with SEN participate in extracurricular training related to their specific difficulty, for which they usually have a lower level of intrinsic motivation and self-esteem (Gooch et al., 2015) and a lower perception of competence in various school subjects (Zisimopoulos and Galanaki, 2009). This can also compromise academic success, as intrinsically motivated children have been shown to exhibit significantly higher academic achievement and more favourable perceptions of their academic

competence (Lepper et al., 2005). Such research highlights the great need to apply teaching strategies that increase motivation in students with SEN.

Focusing, in particular, on research related to the use of gamification with children with SLD, the research of Gooch and colleagues (Gooch et al., 2016) demonstrated how motivation in students with Developmental Dyslexia can increase thanks to the use of a gamified application, specifically ClassDojo. In ClassDojo, interaction takes place between a personalised and individualised design of both the tasks to be performed and the teaching proposed. Furthermore, the authors hypothesised that such results may also be applicable to other students with SEN. However, methods involved the use of badges as the only element of gamification. A badge is usually awarded at a certain time or milestone (Saputra, 2015), meaning that there are time periods when students do not get any motivational elements and only the winner gets the prize. Students who never reach the objective may gradually lack motivation. Continuous encouragement is important for students with Developmental Dyslexia and, in general, for children who have low self-esteem. Therefore, many more game elements are needed to maintain and increase motivation.

In another study (Saputra, 2015), the use of a gamified software, LexiPal, aimed at children with Developmental Dyslexia, was evaluated. LexiPal is characterised by the presence of seven typical game elements, namely story/theme, clear objectives, difficulty levels, points, prizes, feedback, and badges/achievements, each presented in a specific phase of the game, with different purposes. Initially, in Phase 1, story, objectives, and levels are presented to attract the attention of users and make them interested in the topic presented. Subsequently, in Phase 2, at the end of each level, points and rewards are shown, while feedback is given to provide continuous encouragement and motivation during the learning process. Finally, in Phase 3, a badge is awarded to enhance children's achievements and motivate them to achieve even better. After the experience with LexiPal, children with Developmental Dyslexia reported greater commitment, fun and motivation.

iLearnRW game, instead, allowed children with Developmental Dyslexia to work on their reading-writing skills, providing an individualised learning program (Cuschieri et al., 2014). The software, both in teacher's presence and absence, increased the involvement of students and was thus used both within the school context and at home. The game is designed in such a way that the individual continues to practice the activity until they acquire and maintain learned skills, helping to improve both speed and accuracy in reading and writing. The application is characterised by the presence of different characters, each of which represents a specific linguistic difficulty on which the student must practice. In addition, it involves adaptation mechanisms, which track users' progress and adapt accordingly.

Another study (Dymora and Niemiec, 2019) demonstrated the effectiveness of gamification as a support for learning in children with Developmental Dyslexia, in particular who have difficulties in orthography. A gamified application, used on a mobile device (i.e., smartphone), supports orthography rules learning by adopting objectives, levels, points, results, and feedback as motivating elements. There are three sections for each activity: "practice" to improve skills; "game" where competition with other users takes place; and, finally, "assessment" to verify learning. The gamified application was developed and designed to increase the attractiveness of teaching tools and encourage immersive learning. Furthermore, preliminary studies conducted to evaluate its impact on students' performance, showed a lower percentage of errors and omitted words in text dictation.

The research presented so far demonstrates the positive effects derived from the use of gamification to support learning in groups of individuals with SEN, who need individualised and personalised teaching-learning processes, as well as strategies to increase their motivation and self-esteem.

CHAPTER 3 – Experimental studies

3.1 Introduction

Though there is strong evidence to suggest that children can learn also through games (Lillemyr et al., 2011), the effects of gamification are still controversial. Several studies, indeed, highlighted the efficacy of gamification (Aldemir et al., 2018; Egenfeldt-Nielsen, 2006; Hamari et al., 2014; Sailer et al., 2017; Xi and Hamari, 2019), whereas some others reported critical elements or that there is no empirical evidence of a positive impact (Dalmina et al., 2019; Hanus and Fox, 2015; Hyrynsalmi et al., 2017), and this is also true for the educational field (Koivisto and Hamari, 2019).

The recent shift in the focus of research from the elements of gamification to the gameful experience, that is the pursuit of satisfying the intrinsic needs for competence, autonomy, and relatedness (Deci and Ryan, 1985; 2000; Huotari and Hamari, 2017), led to an empirical literature on the relationship between gamification and intrinsic needs satisfaction. The studies are still relatively few, yet indicate positive relationships (Peng et al., 2012; Thom et al., 2012; Bormann and Greitemeyer, 2015; Kim et al., 2015; van Roy and Zaman, 2018). Nonetheless, most of them investigate either a limited set of gamification affordances and/or part of SDT intrinsic needs (Xi and Hamari, 2019).

Although it is certainly fundamental to analyse the effects of the different gamification affordances, the fact that the same gamification element can activate several motivational processes at the same time (Antin and Churchill, 2011), and, vice versa, the same motivational process can be supported by different elements, cannot be ignored. Any motivational valence, also, emerges from the user experience, that is the overall interaction that the user has with an artefact in a particular context (Nicolás et al., 2011). Lastly and most importantly, motivation should emerge not from a single element, but from the whole system, according to a logical perspective. Yet, most literature about gamification concentrates on the study of one — or at most of a few more, but always analysed separately — design elements and imply that each element produces one — and only one — kind of motivational experience across users and contexts (Deterding, 2014).

Thus, not only should research try to systematically study gamification and analyse its effects globally, but ludic-educational design in general should revolve around creating organic and harmoniously implemented motivational products, which should be a coherent and efficient whole, more than the sum of single elements.

In the last almost ten years, what emerged is that the prevalent meaning of gamification is about driving any human activity, through achievements, leaderboards, and other small specific incentives, and tracking it, and this conceptualisation is used by game design industry, but also in business companies and at an academic level. What research should do is to give a positive insight on gamification and the gameful experience it elicits, by addressing the valid criticism it has received and by promoting a systemic analysis and a holistic production of gamified products, in order to improve users' motivational experiences, considering the educational objectives (Alexe et al., 2013) and in accordance with social, psychological and pedagogical aspects (Aldemir et al., 2018; Aura et al., 2021; Deterding, 2014; Hamari, 2019).

Starting from these premises, namely that the different affordances of gamification should be harmoniously implemented — and accordingly analysed — in order to obtain a coherent and efficient whole, the hereby presented research project is specifically aimed at investigating whether gamification, as a complex structure (Hamari et al., 2014; Koivisto and Hamari, 2019) including motivational implementation (or game elements, to induce typical gameful experience; Hamari, 2019), psychological outcomes (or psychological experiences that games and gamification generally promote), and behavioural

outcomes (or better learning outcomes), can improve motivation and reading and writing skills, in eight to ten years old children. On account of this fact, first a pilot study was conducted in accordance with literature (Furió et al., 2013a; Papadakis et al., 2016; Davis et al., 2017), in order to assess the preference, in Primary School children, of using a tablet over PC to perform various activities, including learning activities. Secondly, the effects of two Applications, which combine the training of linguistic skills within one gamified intervention, were compared to that of equivalent, traditional pen-and-paper activities during a 12-hour training at school, distributed over 15 weeks (Study A). Furthermore, the aforementioned effects were compared to those of a 12-hour clinical treatment in 12 weeks, for children with Specific Learning Disorders, specifically with Developmental Dyslexia and/or Dysorthography, using the same gamified Applications (Study B).

3.2 Aims of the studies

Pilot study. The pilot study aimed to clarify the preference of use in children for digital devices, particularly Personal Computers (PC), either laptop or desktop, and Tablet computers, commonly shortened to tablet. The latter, in fact, is the investigative tool that was used in the research project main studies (Study A and Study B), in accordance with literature related to m-learning.
The main objectives of the pilot study were to:

- assess children's use of PCs compared to tablets (e.g., knowledge, modalities, preferences);
- assess children's relationship with PC, tablet, and video games;
- assess children's level of satisfaction with respect to the activities proposed during the workshop, that were gamified linguistic exercises on tablet compared to pen-and-paper linguistic exercises;
- assess children's experience with respect to the use of the gamified Applications.

Study A and B. The objective of research main studies was to assess the effectiveness, in terms of motivation, involvement and improvement of reading and writing skills, of gamified digital Applications through an experimental training in eight to ten years old children, both with typical development (Study A), and with Specific Learning Disorders, with the diagnosis of Developmental Dyslexia and/or Dysorthography (Study B). The effectiveness of the experimental protocol was compared with traditional pen-and-paper control training in Study A, whereas in Study B the effect of Applications' use, equal for all at school, was compared to the effect of a personalised training, based on clinical considerations, for children with SLD.
The two studies had the aim to investigate whether:

- gamified Applications have impact on reading and writing performance, and if said impact is more effective in comparison with that of pen-and-paper learning activities;
- gamified Applications are more effective in motivating and engaging students during learning activities in comparison with pen-and-paper exercises, and if this effect has an impact on reading and writing performances;
- a personalised training, with gamified Applications, for children with SLD is more effective compared to a training proposed in the same way within the class, that is, proposing similar activities between children of the same age and cognitive abilities;
- different gameful experiences, based on gamification affordances, have a different impact on improvements in linguistic performances.

3.3 Pilot study

3.3.1 INTRODUCTION

M-learning, or Mobile Learning, refers to the acquisition of knowledge and skills through mobile devices, such as laptops, tablets, and smartphones, and thus learning takes place anywhere and at any time (Sharples et al., 2002; Noriega, 2016). The application of m-learning does not substitute a more traditional way of learning, but rather acts as an integration of learning activities in the educational context, both formal and informal (Martin and Ertzberger, 2013), also because not all contents and competences can be conveyed through mobile technology.

In order for m-learning to be effective, used contents should be highly engaging and short, to allow constant feedback (Looi et al., 2010), whereas devices should be highly portable, available anytime and anywhere, adaptable, persistent, useful for diverse individual needs, easy to use and, therefore, intuitive for those who have no experience with technologies (Sharples, 2000).

In today's digital society, the beneficial features of mobile learning are thus:

- *mobility* - devices' portability enable learners to use them anytime and anywhere, either at school or in extra-curricular spaces (M. Sharples et al., 2005; Nordin et al., 2010);
- *wireless networking* - this allows learners to have limitless Internet connection and new conception of lifelong learning (M. Sharples et al., 2005);
- *interactivity* - learners can interact with each other, regardless of distance, and interpersonal communication proved fundamental for education (Nordin et al., 2010);
- *accessibility* - this enables learners to get information immediately and to reflect on acquired knowledge to form new one (Nordin et al., 2010);
- *privacy* - learners are able to access their own data, at their current learning level, thus feeling safe and motivated (Zhang, 2003; Bidin and Ziden, 2013).

Such features make the educational process flexible for both students and teachers; they also allow immediate communication between the people involved in the educational process, and constant monitoring, even at a distance (Sharples, 2002). Moreover, m-learning features leverage on factors contributing to effective learning (M. Sharples et al., 2005), that are:

- *learner* centred - learning is developed from students' own previous knowledge and skill;
- *knowledge* centred - learning comes from validated knowledge, taught by using different methods;
- *assessment* centred - learners are assessed based on their ability and further guided;
- *community* centred - an effective learner forms a community to share knowledge and support others.

The usability and perceived ease of use of mobile devices are considered an important factor influencing educational effectiveness (Mayes and Fowler, 1999). A preference for touch interaction, rather than by pressing buttons, also emerged in literature (Furió et al., 2013a). The difference in the type of device used, on the other hand, proved to be irrelevant to the learning, usability, or engagement of Primary School children (Furió et al., 2013a). The main difference between smartphones and tablets is in the weight and the size, but this did not determine a change in the expected results.

In a more recent study (Davis et al., 2017), however, Second Grade Secondary School students had to answer questions relating to the teaching of science, mathematics and reading, using a tablet or a computer. It was found that, regarding the disciplines of science and mathematics, there are no significant differences between the use of the two devices, whereas the use of tablet is preferable for reading, especially for males. This result is surprising, as there are technical limitations regarding the tablets, such

as screen size and stimuli presentation, the need to scroll the text, eye fatigue due to closer proximity to the screen and its brightness, and so on. However, tablets are preferable for reading as the possibility of scrolling through the screen seems to recall the natural gesture of the fingers, while the use of mouse as an intermediary is less immediate. Further studies have then shown that tablets are also more effective in the development of mathematical skills, regardless of age and gender, in preschool children (Papadakis et al., 2016).
Not less importantly, mobile devices make the learning process more accessible, due to the great availability of such tools at home, their portability and low cost. Such benefits have also been reported for students with neurodevelopmental disorders (Kagohara et al., 2013).

3.3.2 PARTICIPANTS

The pilot study involved twenty-one children, seven to twelve years old, within the Summerlabs initiative for children of the University of Trento staff in collaboration with the Observation, Diagnosis and Training Laboratory of Rovereto (ODFLab - Laboratorio di Osservazione, Diagnosi e Formazione). Two of the participants interrupted the activities before the end of the workshop and one of them did not take part in the study but completed some activities along with the other children. Any personal sensitive and non-sensitive data were not collected, but parents of the participating children gave informed consent to the workshop organisers.

3.3.3 MATERIALS AND METHODS

The following materials were used:

- posters;
- happy/sad face smiley stickers;
- coloured pens;
- Post-it Notes;
- 11 tablets, different from each other as for ergonomic characteristics and manufacturer (Apple: iPad, iPad mini; Samsung Tab S2; Huawei MediaPad T3), but all with minimum requirements to run the two gamified Applications Dislessia Evolutiva (Savelli and Pulga, 2016) and Recuepero in Ortografia (Ferraboschi and Meini, 2016);
- printed exercises sheets from Dislessia e trattamento sublessicale (Cazzaniga et al., 2005) and Recupero in ortografia (Ferraboschi and Meini, 2014);
- printed sheets with activities images;
- printed fun-meters.

The pilot study, which had a duration of 90 minutes, was set up as follows.

1. For 30 minutes and using posters, Post-it Notes and smiley stickers, the experimenter collected children's anonymous opinions related to their knowledge and attitudes towards the digital devices under study.
2. For the next 40 minutes, children, divided into two groups, completed two types of activities in alternating order:
    a. linguistic exercises with gamified Applications on a tablet;
    b. pen-and-paper linguistic exercises.
3. During the last 20 minutes, children expressed their general satisfaction for the activities by colouring a fun-meter and using happy/sad face smiley stickers.

By using happy or sad face smiley stickers, corresponding to 'yes' and 'no' respectively, and/or writing their answers on a Post-it Note, during the first 30 minutes phase, children were asked to answer the following questions:

- *What can I do with the PC/tablet?*
    - basic operations;
    - using the Internet;
    - using different software/Applications.
- *How do I use the PC/tablet?*
    - I use it *n* hours per day;
    - I only use it at school;
    - I mostly use it at school/at home.
- *What do I do with the PC/tablet?*
- *What kind of video games do I play?*
- *Do I prefer using the PC or the tablet? Why?*

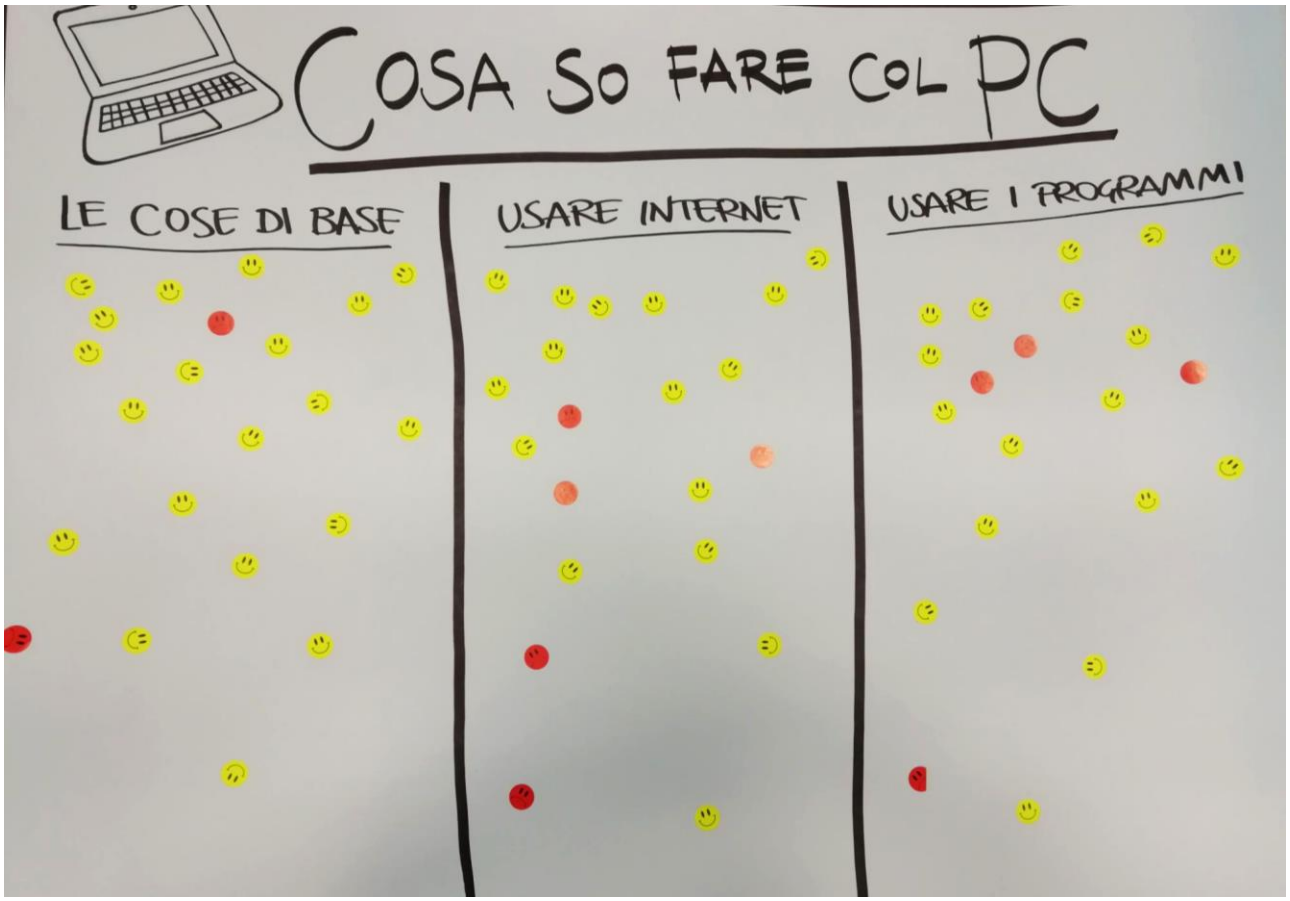

Figure 9. Children's answers to the question 'What can I do with the PC?'; yellow happy face smiley stickers correspond to 'yes', whilst red sad smiley stickers correspond to 'no'

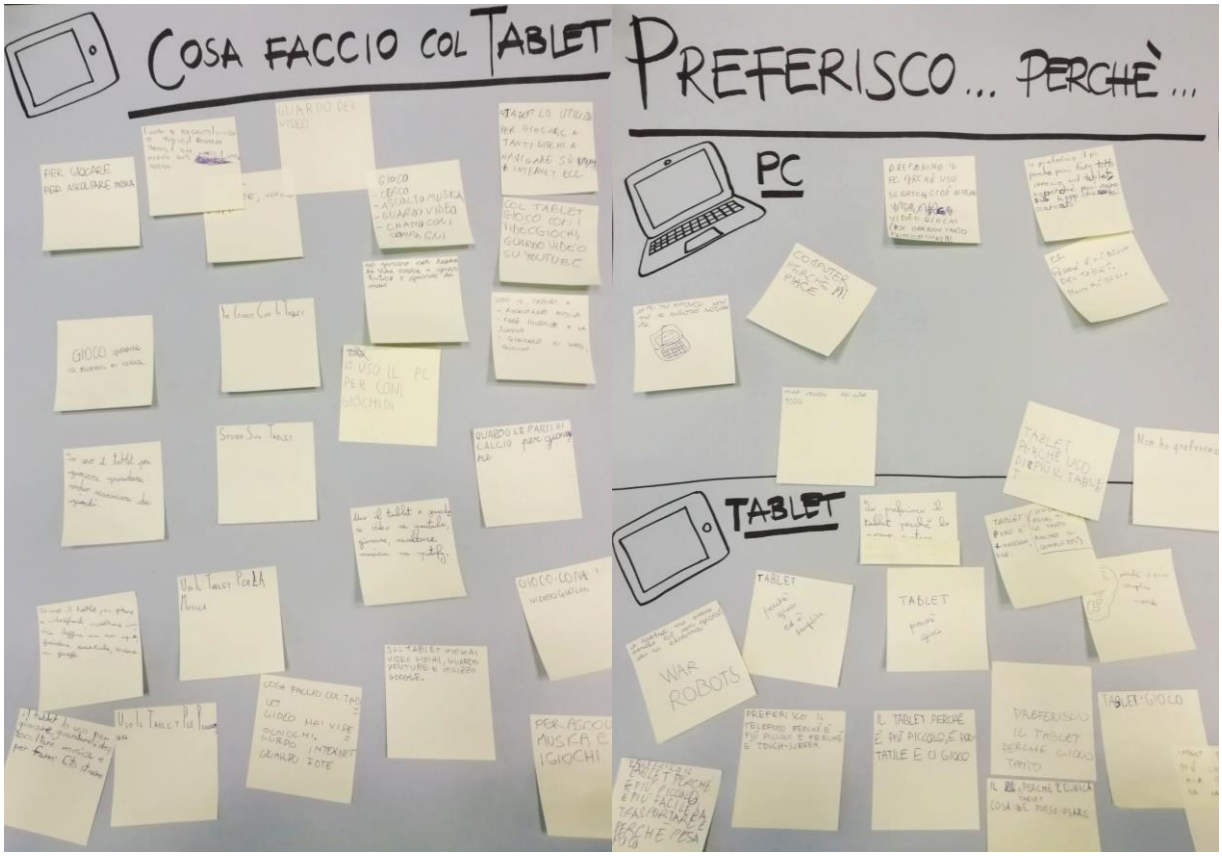

Figure 10. Children's answers, elaborated on Post-it Notes, to the questions 'What do I do with the tablet?' and 'Do I prefer using the PC or the tablet? Why?'

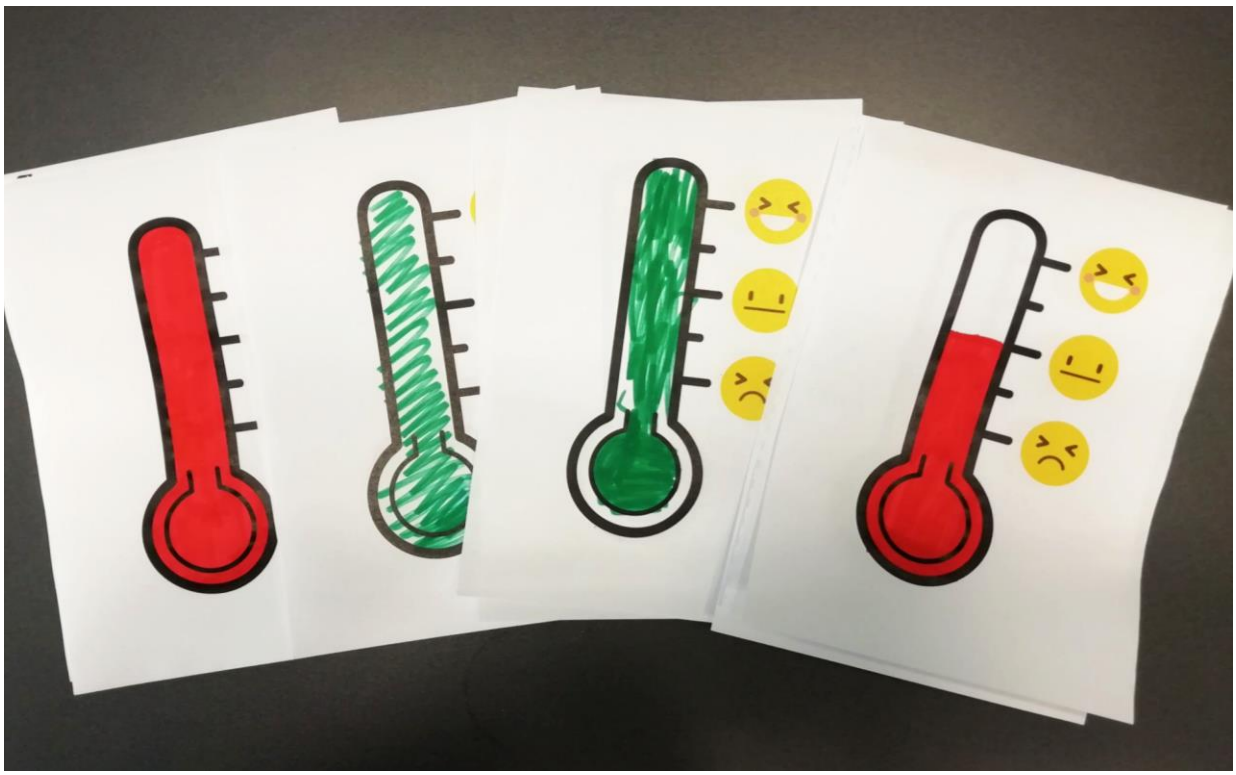

Figure 11. Some coloured fun-meters, representing children's general satisfaction for the activities

3.3.4 RESULTS AND DISCUSSION

According to the collected data, children seem to know how to use digital devices (both PC and tablet) to the same extent, with regards to basic operations, use of the Internet and of software/Applications (Fig. 12).

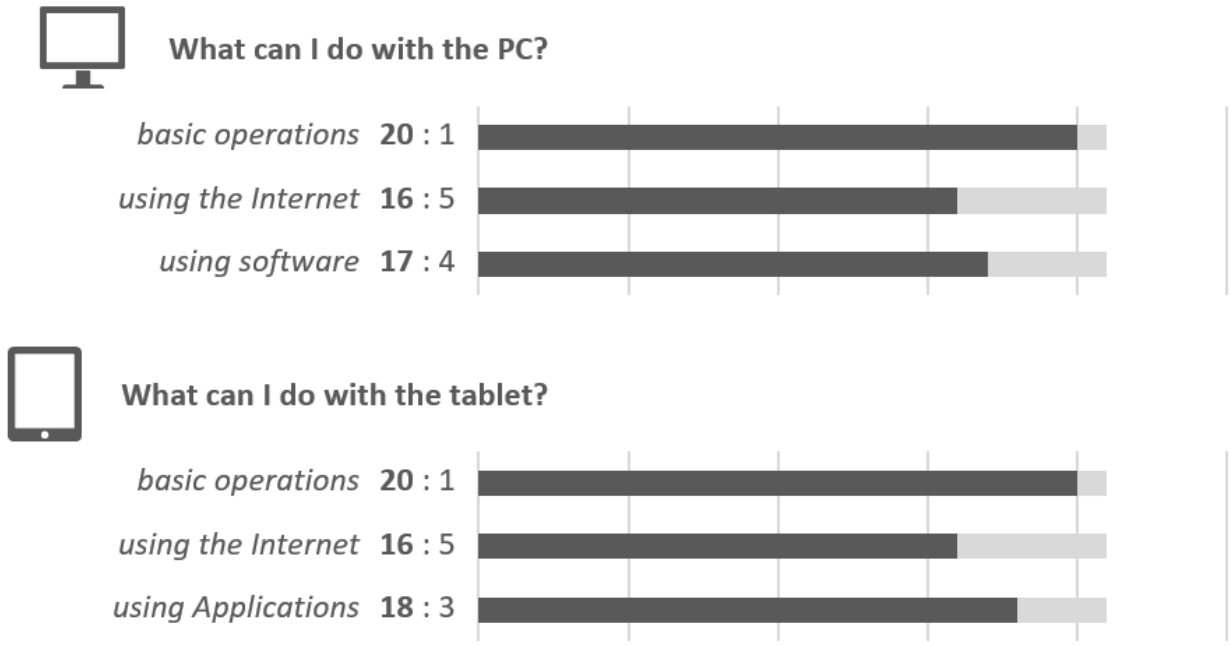

Figure 12. Children's general knowledge and use of digital devices (PC and tablet)

Children generally use tablets more than the PC and for longer periods (Fig. 13). This could possibly be explained by the kind of activities they engage in while using the two different devices. Reportedly, children do not use tablets at school, due to the lack of devices and/or poor implementation of BYOD policies, whereas they partly use the PC at school, generally in the multimedia classroom. Children also report they prefer to use the tablet, mostly because it is easier to handle and to interact with, thanks to the touchscreen.

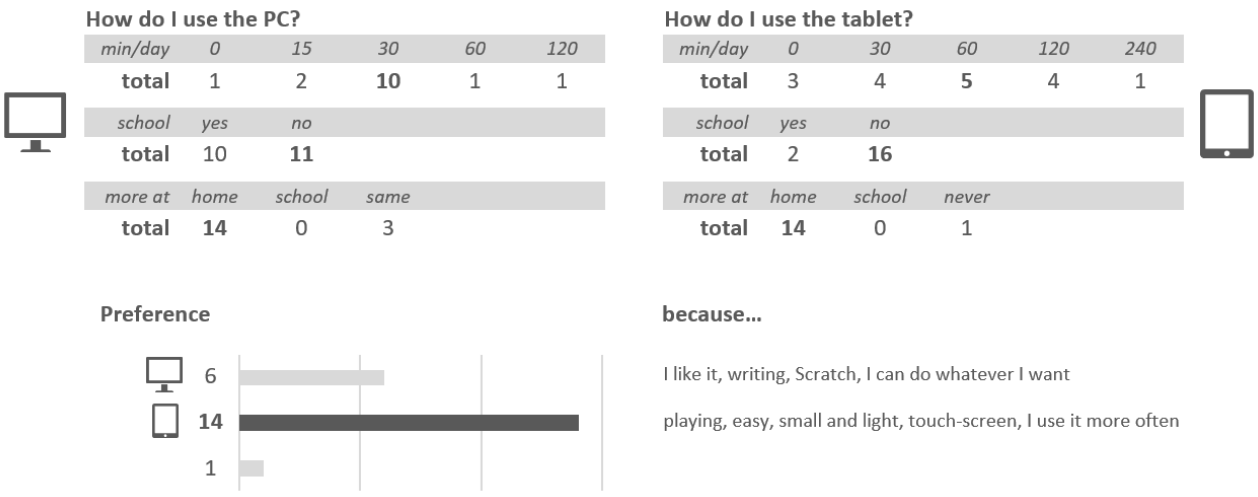

Figure 13. Children's modalities of use and preferences for PC and tablet

When using the PC, apart from playing, children mostly navigate the Internet, also for didactic purposes, and write (Fig. 14).

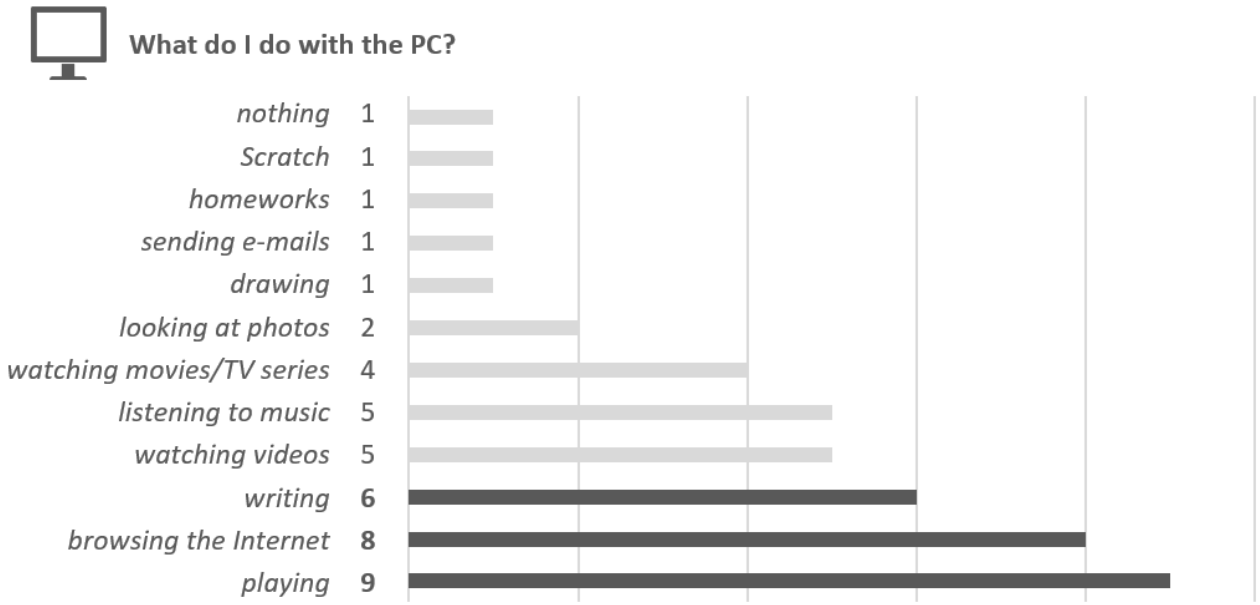

Figure 14. Principal activities of children at the PC

With the tablet, instead, children mostly play, watch videos, listen to music, and navigate the Internet (Fig. 15).

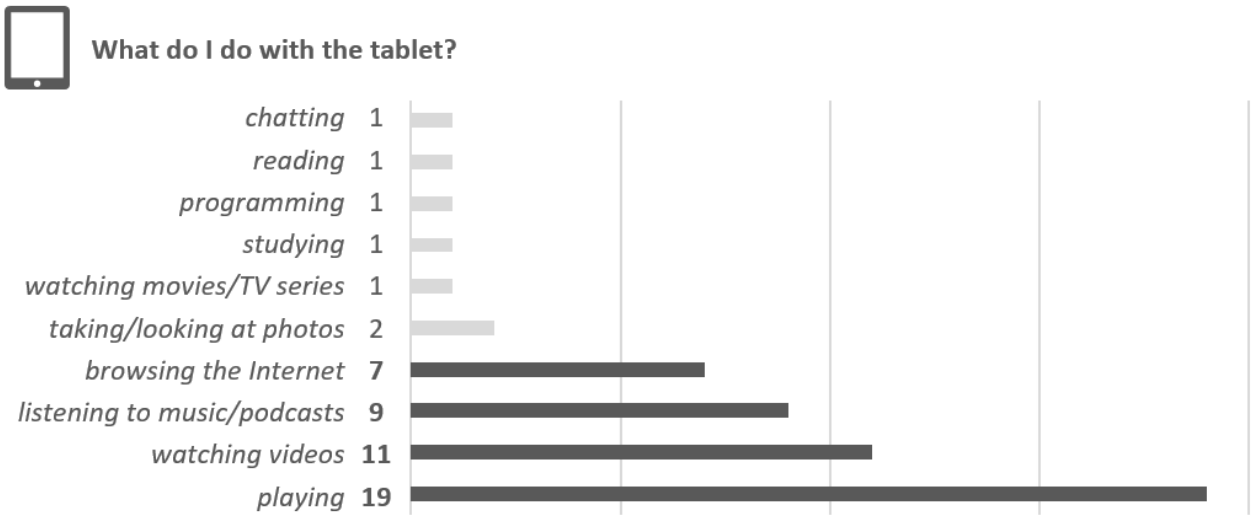

Figure 15. Principal activities of children on the tablet

The video games preferred by children involved in the pilot study are mostly arcade games and multiplayer strategy games (Fig. 16). There are very few video games that children play on PC or console (i.e., Minecraft, Fortnite, Fifa, Super Mario Cart 2, Zelda), a confirmation to the fact that the preferred gaming platforms are portable devices, such as smartphones and tablets.

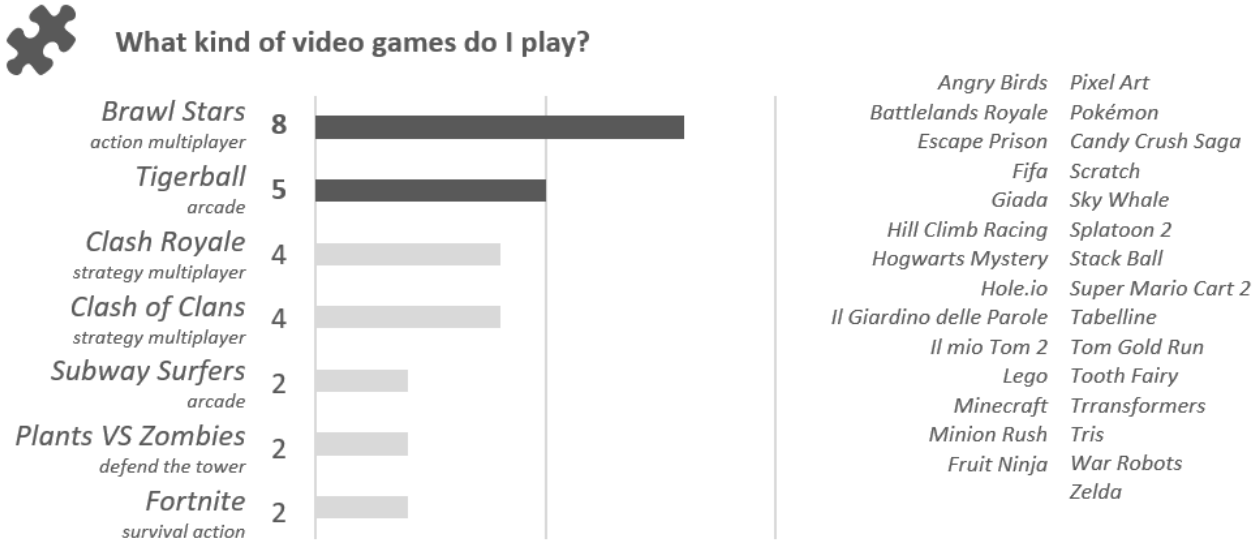

Figure 16. Video games mostly played by children on different devices (PC, tablet, smartphone, console)

The participants to the pilot study generally enjoyed the workshop activities, and most of them preferred to complete the linguistic exercises with the gamified Applications on tablet instead of doing exercises on paper sheets (Fig. 17).

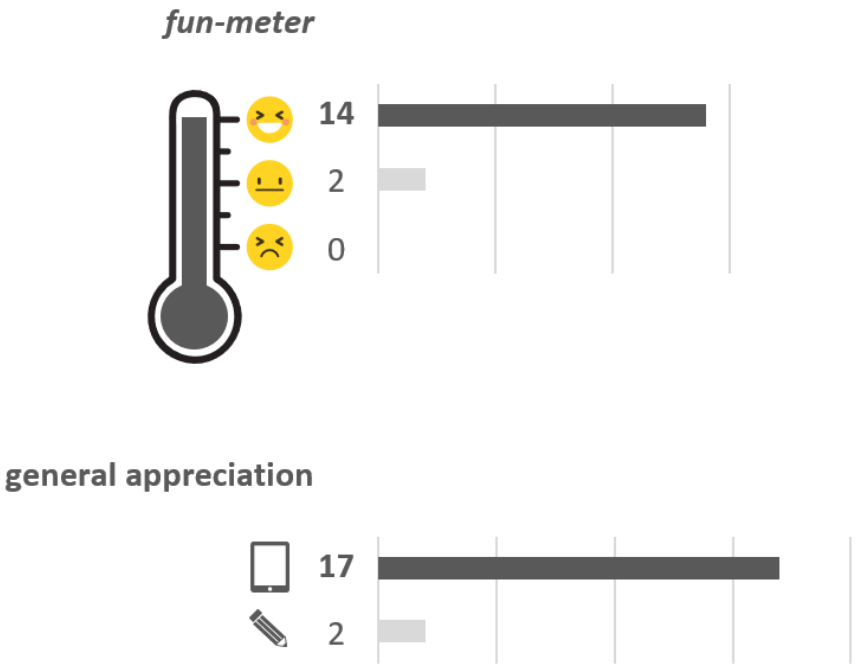

Figure 17. Children's level of satisfaction for workshop activities and general preference for exercises modality

Both gamified Applications, Dislessia Evolutiva and Recupero in Ortografia, aimed at improving children's linguistic skills through motivating and engaging exercises, received positive feedback from the participants (Fig. 18). Children most used to playing with the tablet and more complex video games are probably those who liked the proposed activities less.

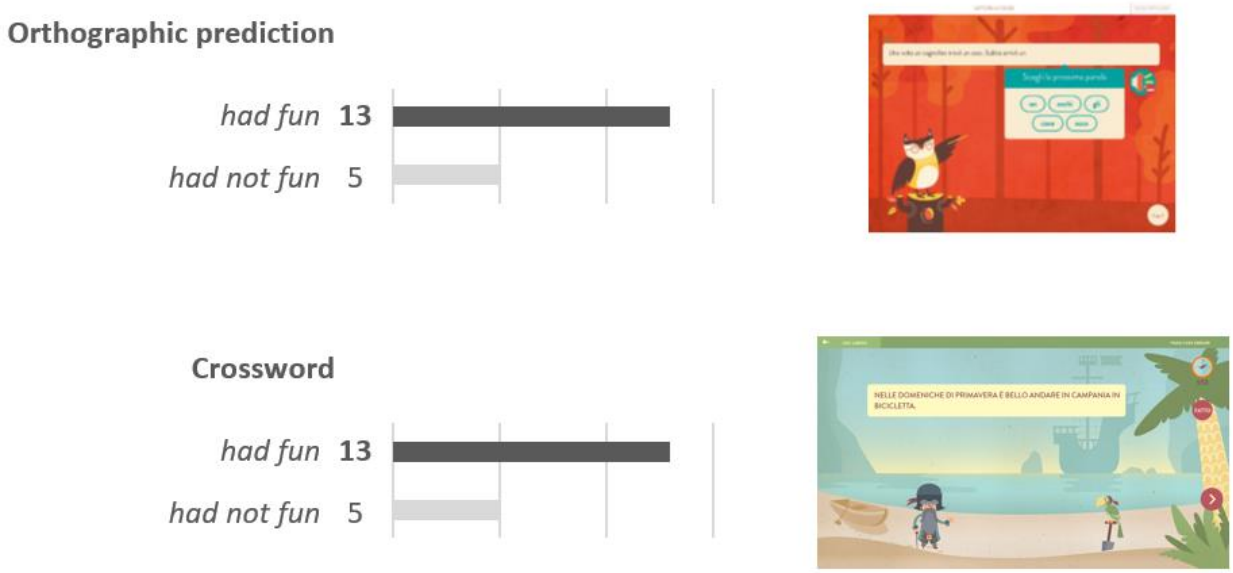

Figure 18. Children's engagement in tablet activities

3.4 Study A

3.4.1 INTRODUCTION

In recent decades, growing evidence on the possible positive effects of the use of gamification in education was collected (Lee et al., 2013; Koivisto and Hamari, 2019). Despite promising results, it should be mentioned that these past studies showed some limitations (i.e., they investigate a limited set of gamification elements, they lack the use of controls, they predominantly focus on quantifiable learning outcomes, etc. Majuri et al., 2018; Koivisto and Hamari, 2019; Xi and Hamari, 2019).

Therefore, the aim of the present study was to investigate whether two Applications, Dislessia Evolutiva (Savelli and Pulga, 2016) and Recupero in Ortografia (Ferraboschi and Meini, 2016) that combine the training of several linguistic skills within one gamified intervention, might have a positive effect not only on learning, specifically on literacy skills, but also on students' motivation and on their Intrinsic Needs Satisfaction, in accordance with literature (Deci and Ryan, 2000; Huotari and Hamari, 2017; Hamari, 2019).

On account of this, first the training effects (both educational and motivational) of said gamified Applications were assessed in a school-based study with typically developed children. Secondly, such effects were compared with those that standardised, equivalent pen-and-paper activities had on control groups.

Specifically, significant intra-group improvements are expected to be observed for all conditions examined, since both interventions had been proven effective in previous studies, as well as higher improvements in literacy skills, which are specifically addressed by the two Applications, for the experimental groups compared to the control groups, due to the type of activity. In addition, it was argued that the enjoyment experienced during the activities along with Intrinsic Needs Satisfaction should lead to a significant improvement in performance following the training.

In the next part of the chapter, Study A is presented.

3.4.2 HYPOTHESES

As per research results, the following hypotheses were expected to be verified.
H1. Experience of training, either gamified or pen-and-paper, is positively associated with better performances in reading and writing tests, as per time factor, comparing pre- and post-training results for both experimental and control groups.
H2. Greater performance improvements, between pre- and post-training reading and writing tests, are more strongly predicted by experimental gamified training than pen-and-paper activities, in post-training reading and writing tests, in terms of correctness and speed.
H3a. Having fun during the training activities is positively associated with improvements in reading and writing performances, for both experimental and control groups.
H3b. Intrinsic Needs Satisfaction has a positive impact on performance improvements, for both experimental and control groups, and acts as a mediator.
H4. Gameful experience positively predicts improvements in reading and writing skills.

3.4.3 PARTICIPANTS

The study included two groups of eight to ten years old children, attending the third, fourth and fifth class of Primary School.
Participation was voluntary and, involving minors, required the submission to parents (or legal tutors) of informative documentation regarding research contents, tools and the guarantee of confidentiality and anonymity of the data obtained during the study. The information process was considered essential for the conscious provision of consent to participation and data processing. Furthermore, it positively favoured a relationship of trust between the principal investigator, the teachers, the families, and the children. Each participant was free to withdraw from the study at any time and without any consequences. No data, relating to performances of children whose parents did not give informed consent to participate, were collected either before or after the training. However, to avoid exclusion and isolation phenomena and in agreement with the teacher in charge of the classes, those children remained inside the class, along with their classmates, during the experimental activities.
The subjects who gave voluntary consent to participate in the research were one hundred ninety-seven (197), divided into the Comprehensive Institutes of Pergine 2 and North Rovereto. The different school classes were randomly assigned to the experimental and control conditions; no differences in the expectations of the two groups of teachers and parents were created as it has been explained that the two interventions had been both proven effective in previous studies. Table 5 shows, in detail, the schools and classes attended by the children who took part in the study, as well as the specific type of activity proposed and the possible presence of subjects with a non-specific diagnosis and/or bilingualism (Italian and other language, as opposed to Italian native monolingualism; Riva et al., 2021).

Table 5. Distribution of children by Institute, class, and experimental condition

School	Class	Type of training	N (tot = 197)	Sex	Difficulties and/or Bilingualism
Pergine 2 (Rodari)	3^A	APP - Recupero in Ortografia	13	M = 4 F = 9	4
Pergine 2	3^B	EX - Recupero in	14	M = 7	6

(Rodari)		ortografia		F = 7	
North Rovereto (Noriglio)	3^A	APP - Dislessia Evolutiva	23	M = 10 F = 13	3
North Rovereto (Gandhi)	3^A	EX - Dislessia e trattamento sublessicale	23	M = 11 F = 12	11
Pergine 2 (Canale)	4^A	APP - Dislessia Evolutiva	13	M = 6 F = 7	2
Pergine 2 (Canale)	4^B	EX - Dislessia e trattamento sublessicale	12	M = 6 F = 6	2
North Rovereto (Noriglio)	4^A	APP - Recupero in Ortografia	14	M = 8 F = 6	2
North Rovereto (Noriglio)	4^B	APP - Recupero in Ortografia	14	M = 8 F = 6	1
North Rovereto (Gandhi)	4^B	EX - Recupero in ortografia	13	M = 7 F = 6	1
Pergine 2 (Madrano)	5^A	EX - Dislessia e trattamento sublessicale	9	M = 4 F = 5	-
Pergine 2 (Madrano)	5^B	APP - Dislessia Evolutiva	12	M = 7 F = 5	3
North Rovereto (Noriglio)	5^A	APP - Recupero in Ortografia	15	M = 7 F = 8	1
North Rovereto (Gandhi)	5^C	EX - Recupero in ortografia	22	M = 14 F = 8	8

During the final data analysis, all children who made a number of training absences equal to or greater than four were excluded, as the acquired data would have been less reliable (N = 2). Some children withdrew from the research project during the training phase, while some others were excluded because they were absent during the final meeting of the project and/or during the final test phase (N = 12). Furthermore, due to the COVID-19 emergency, it was not possible to collect post-training data for some children attending the fifth grade of Primary School, having passed, in the following September, to First Grade Secondary School (N = 37).

Therefore, the final sample consisted of one hundred forty-six (146) subjects (N = 81 for the experimental group, N = 65 for the control group), of which 78 Females (53.42%) and 68 Males (46.57%), mean age 9,16 (SD = 0.92) years. The study was quasi-experimental, because it was not possible to randomly assign participants to the experimental or control groups. However, no significant differences were found between the groups for demographic and cognitive characteristics, and literacy scores at T1. Also, no significant difference was found, in both experimental and control groups, in T2 scores due to

different timing in collecting post-training data. The descriptive statistics of the groups are reported in Table 6.

Table 6. Demographic and cognitive characteristics, and literacy scores (Means, SD) of experimental and control groups prior to training

[a] Experimental group, APP Recupero in Ortografia

[b] Control group, Recupero in ortografia

[c] Experimental group, APP Dislessia Evolutiva

[d] Control group, Dislessia e trattamento sublessicale

[e] $\chi 2$-value, [f] T-value, * sig. $\alpha < 0.05$

	E1 group[a] (n=32)		**C1 group[b] (n=18)**				**E2 group[c] (n=35)**		**C2 group[d] (n=28)**			
	M	*SD*	*M*	*SD*	*Test*	*p*	*M*	*SD*	*M*	*SD*	*Test*	*p*
Sex (F-M)	17-15		10-8		0.02[e]	0.87	18-17		14-14		0.01[e]	0.91
Age (years)	9.12	0.75	8.94	0.72	0.87[f]	0.39	9.08	0.91	9.21	0.96	0.52[f]	0.60
IQ (RM)	12.62	4.16	13.05	3.65	0.38[f]	0.70	13.68	4.06	13.25	3.87	0.51[f]	0.61
LINGUISTIC SKILLS												
Word												
Speed (syll/sec)	-0.72	1.04	-0.19	1.19	1.47[f]	0.15	-0.20	1.06	-0.20	0.78	0.03[f]	0.97
Accuracy (errors)	-1.48	2.10	-0.93	1.66	1.05[f]	0.30	-0.56	1.26	0.01	1.23	2.10[f]	0.04*
Non-word												
Speed (syll/sec)	-0.46	0.94	-0.10	1.05	1.15[f]	0.26	-0.17	0.91	0.03	0.87	0.93[f]	0.36
Accuracy (errors)	-1.20	1.40	-0.63	1.32	1.57[f]	0.12	-0.31	1.12	0.07	0.98	1.46[f]	0.14
Text												
Speed (syll/sec)	-0.80	1.07	-0.38	1.15	1.19[f]	0.24	-0.51	1.03	-0.21	0.95	1.24[f]	0.22
Accuracy (errors)	-1.94	2.12	-1.59	1.94	0.70[f]	0.50	-0.99	1.17	-0.89	1.50	0.32[f]	0.75
Writing												
Accuracy	-2.30	3.01	-2.33	2.98	0.04[f]	0.97	-1.84	2.48	-1.30	3.19	1.17[f]	0.25

(errors)

In the subsequent analysis phase, participants whose native language was not Italian and/or with other psychopathological and/or developmental disorders (unspecified, for privacy) were excluded, as these conditions could explain poor performances in reading and writing tasks (N = 33). These subjects, however, formed two subgroups of participants, subsequently compared with Study B group of children with a diagnosis of Developmental Dyslexia and/or Dysorthography.

3.4.4 TOOLS

The tools used for the study are detailed below.
During the initial phase (T1), the general intellectual ability was investigated using the subtest Reasoning with Matrices, part of the WISC-IV scales. Furthermore, a questionnaire related to school well-being (QBS-B) was administered.
Neuropsychological tests were used to analyse the difference between pre- (T1) and post training performances (T2), in particular tests investigating reading and writing skills (DDE-2, MT-3, and BVSCO-2).
Lastly, in order to assess children's motivation and general appreciation for the activities, a questionnaire, specifically designed on the basis of the different training, was used (T2).
With regards to the training activities, the Applications Dislessia Evolutiva (Savelli and Pulga, 2016) and Recuepero in Ortografia (Ferraboschi and Meini, 2016) were used with experimental groups. Applications were installed on mobile devices (tablets) that were different from each other as for ergonomic characteristics and manufacturer (Apple: iPad, iPad mini; Samsung Tab S2; Huawei MediaPad T3).
For control groups, two paper books were used, Dislessia e trattamento sublessicale (Cazzaniga et al., 2005) and Recupero in ortografia (Ferraboschi and Meini, 2014). Both books propose exercises equivalent to those available in the two Applications.

3.4.4.1 *WISC-IV: Wechsler Intelligence Scale for Children-IV*
(Orsini et al., 2012)

It is a clinical tool for assessing the cognitive abilities of children aged between 6 years and 0 months and between 16 years and 11 months. The battery consists of ten main and five additional subtests, which are essential for the calculation of five composite scores (as well as the total IQ score).
For this study, in particular, the subtest Reasoning with Matrices was used, which allows an estimate of fluid intelligence, defined as the ability to think logically, and solve problems in new situations, regardless of previously acquired knowledge. In addition, it provides information on the ability to classify, attention to detail and ability to analyse the stimulus, maintenance of attention, visual-perceptual discrimination, and the ability to identify regularities in visual stimuli, skills that are also useful during the reading process.

3.4.4.2 *QBS 8-13: Questionari per la valutazione del benessere scolastico e identificazione dei fattori di rischio*
[Questionnaires for the assessment of school well-being and identification of risk factors] (Marzocchi and Tobia, 2015)

This tool allows researchers to investigate different aspects of the school life of eight to thirteen years old children, providing a picture of school well-being. It is composed of different questionnaires that have to be separately filled out by students, parents, and teachers, in order to obtain three different points of view regarding the same situation. During Study A, only the questionnaire for the child, that is the QBS-B, was completed in paper form, addressed to pupils from the third class to the fifth class of Primary School.

The questionnaire consists of twenty-seven items, divided into five subscales, which allow to obtain partial scores to subsequently obtain the total academic well-being score:

1. satisfaction and recognition - the four items investigate the pupil's satisfaction with their school results in relation to their commitment and skills, recognised by parents and teachers;
2. relationship with teachers - the five items assess the level of trust in teachers and the pupil's perception of their emotional availability and their support and recognition;
3. relationship with classmates - the five items investigate how much the child feels accepted and part of the group and the level of trust they have towards their classmates and the presence of meaningful relationships with peers;
4. emotional attitude at school - the four items allow to evaluate the emotional reactions of children to school requests and to search for any feelings of anxiety, shame, and guilt;
5. sense of self-efficacy - the six items investigate the child's perception of self-efficacy in relation to cognition and learning.

There are also three items that are not used to calculate school well-being but are useful for the qualitative evaluation of the causal attribution mechanisms applied by the child.

Each of the items provides a response on a three-point Likert scale, with the labels "not true", "fairly true", "very true", which indicate the degree of agreement of the child with the statement. The results of the five indices are expressed in standardised scores (T-scores).

The tool was used because the school environment is the place where the child spends most of the time and it is, therefore, very important to investigate and assess not only the aspects related to performance, but also those related to the relational and emotional sphere that are at the base of the construction of the idea of self and of the possible meaningful relationships with classmates and teachers.

3.4.4.3 *DDE-2: Batteria per la valutazione della Dislessia e della Disortografia Evolutiva-2*

[Battery for the assessment of Developmental Dyslexia and Dysorthography-2] (Sartori et al., 2007)

Currently, it is the most effective tool for assessing the level of competence acquired in both reading and writing and is included in the basic diagnostic protocol for assessing the presence of a Specific Learning Disorder, approved by the Italian Dyslexia Association.

It can be used starting from the second grade of Primary School up to the third of the Lower Secondary School and it allows to record the performance of the subjects and to analyse the improvements that may be due both to the natural evolution of the disorder and to an intervention program.

For the purposes of the research, the following tests were selected, which allow to calculate the indices of speed (syllables per second) and accuracy (number of errors) in the reading ability:

- test 2, word list reading - the child is asked to read aloud four lists of 28 words (concrete or abstract), varying in frequency (low or high) and length (four to eight letters), as quickly as possible and with the lowest number of errors. The test assesses the ability to decode written stimuli in an isolated way and therefore not inserted in a meaningful context;
- test 3, non-word list reading - the child is asked to read aloud three lists of 16 non-words, namely sequences of letters (varying from five to nine letters) that are similar, as respecting the

phonotactic restrictions of Italian language, to a real word but that is not accepted as such by native speakers. The test evaluates the grapheme-phoneme conversion ability.

As for accuracy, a maximum of one error is attributed for each wrong word and self-corrections are not considered as errors, since they affect the time taken to read the entire list of words. Furthermore, in the case of children with phonetic or articulatory difficulties, the incorrect pronunciation of words is not considered as an error.

3.4.4.4 *Prove MT avanzate-3-clinica*

[Advanced clinical MT trials-3] (Cornoldi and Carretti, 2016)

These tests allow researchers to evaluate the understanding of a written text and its decoding in children attending Primary School and Lower Secondary School. For the purposes of the research, only the decoding tests were used, which allow to identify the speed and accuracy in reading aloud a text, different for each class attended. Indeed, the variables that contribute to identifying a text as suitable for different school levels are the length of the text, the length of the words by which it is composed, the repetitions and the frequency of use of the words. Text length (from 250 to 500 syllables) and complexity increase with grade level with specific norms associated with each grade.

In particular, the tests relating to the Primary School that were used are:

- "Il gerbillo" [The gerbil] for the third class;
- "I Tuareg" [The Tuareg] for the fourth class;
- "Il bumerang" [The boomerang] for the fifth class.

Speed is the parameter for evaluating the level of automation of the reading process and is expressed in syllables per second. Accuracy, on the other hand, indicates how adequate the grapheme-phoneme conversion mechanism is and is expressed in the number of errors.

In order to estimate the accuracy index, the following scores are assigned to errors committed by the child:

- 1 point - incorrect syllable reading, omission of syllable, word or line, addition of syllable or word, rereading of a line, pause for more than five seconds;
- ½ point - accent shift, big hesitation, self-correction for 1 point error, 1 point errors that do not change the meaning of the sentence;
- 0 point - self-correction on ½ point error;
- more errors on the same word are counted only once.

For those who took longer than the predetermined time to complete the reading of the entire text (four minutes), the exact point at which the child arrived at the end of the time was marked and, subsequently, the accuracy index was calculated making an estimate of the errors that the subject could have committed if he had finished reading the passage in the set time using the following formula:

$$total\ errors\ =\ (errors\ made\ *\ nr.syllables\ of\ the\ text)\ /\ nr.syllables\ read\ in\ 4\ minutes$$

3.4.4.5 *BVSCO-2: Batteria per la valutazione della scrittura e della competenza ortografica-2*

[Battery for the assessment of writing and orthographic competence-2] (Tressoldi et al., 2013)

Based on the orthographic learning, by which the learning process is divided into alphabetic, orthographic, and lexical phases, BVSCO-2 represents a complete tool for the evaluation of all the aspects involved in the writing skills learning process (graphism, orthographic competence, production of the written text) and estimates the competence of Primary and Lower Secondary School children.

For the purposes of the research, only the test of orthographic competence, that is the dictation of a specific text for each class, was used. In particular:

- "Il leone e il gallo" [The lion and the rooster] for the third class;
- "Indiani e bisonti" [Indians and bisons] for the fourth class;
- "Il colore dei pesci" [The colour of fishes] for the fifth class.

The dictation was performed by repeating the different fragments of text only once, with a constant speed, to ensure that most of the children were able to write as many words as possible. The performance, to be considered valid, must not contain more than 15% of omissions. During the correction, three main categories of errors were identified, namely phonological, non-phonological, and accents and double letters, and the sum of these errors provided indications on the performance of the subject.

3.4.4.6 *Questionnaire about Gameful Experience and Intrinsic Need Satisfaction*

The questionnaire (see APPENDIX A), which is based on various tools evaluated in related literature, is divided into three parts, only the last of which was submitted to all research participants. The first two, on the other hand, were submitted only to the participants of the experimental groups, as they relate to the experience that the user had with the Applications.

After a first question regarding the general satisfaction with the training activities, the first part proposes the validated Gameful Experience Questionnaire (GAMEFULQUEST), as it was conceived by the authors (Högberg et al., 2019). The tool, designed to model and measure the user experience with gamified Applications, services and systems, was defined starting from a qualitative approach that allowed to describe the gaming experience through components that, subsequently, were grouped into seven dimensions tested with a quantitative approach. The seven dimensions, with which it is possible to describe the gamified experience, are:

1. *accomplishment* (8 items), which is related to goals and completed tasks that are drive to progress and improvement;
2. *challenge* (7 items), which is related to the difficulty of a task and aims at testing user's ability and skill-building;
3. *competition* (7 items), which is related to both competitive aspects of the Application and to the sense of pride derived from being winners among other users;
4. *guided* (7 items), which is related to feeling guided through a structured work program and obtaining feedback related to the performance in order to improve the target behaviour;
5. *immersion* (9 items), which results in the user's attention being completely focused on the activity such that they feel detached from the real world and the behaviour becomes less effortful;
6. *playfulness* (9 items), which is related to feeling involved in voluntary and pleasant actions without any sense of obligation or oppression, everything is driven by imagination and desire to explore;
7. *social experience* (8 items), which is related to the experience resulting from the direct or indirect presence of people, which is enough to generate a sense of support and encouragement in the user.

Dimensions and items were proposed, each time, in random order and the answers, on a 7-point Likert scale, ranged from "strongly disagree" to "strongly agree".

The second part of the questionnaire, based on recent works (Hassan and Hamari, 2019; Koivisto and Hamari, 2019) which also validated the questionnaire items, investigated the user's motivation, considered the most important force behind the implementation and maintenance of a behaviour. The main goal of gamified systems is to promote autonomous and intrinsic motivation through a pleasant, stimulating, and constructive user experience. To analyse this, the items of the questionnaire investigated the elements of

immersion (avatar, guiding character, narrative context, personalisation), achievement (challenges, trophies, feedback, progression) and social (competition), as well as prompts, which together promote the satisfaction of the main needs of the individual (Koivisto and Hamari, 2019; Xi and Hamari, 2019). Participants were asked to indicate, on a 7-point Likert scale, the frequency with which they interacted ("never", "every time") or the importance they gave to the interaction ("not important", "very important") with precise gamified elements:

- immersion (8 items);
- achievement/progression (12 items);
- social (2 items);
- prompts (4 items).

In this case, the items were accompanied by images relating to the two gamified Applications so children could better understand what the different statements referred to.

The third and last part of the questionnaire was aimed at investigating the needs of competence (3 items), autonomy (3 items) and relatedness (3 items) on a 7-point Likert scale in which the participant was asked to indicate how much, for them, some statements relating to the use of the Application or the performance in pen-and-paper activities were true ("not true", "completely true") (McAuley et al., 1989; Richer et al., 1998). The last item was an open question in which the child could write a suggestion for improvement or indicate their own personal judgment with respect to the activity performed. The last part of the questionnaire, although based on validated instruments, was created, and directly used in the studies without a previous validation process.

3.4.4.7 *Dislessia Evolutiva*

(Savelli and Pulga, 2016)

The Application Dislessia Evolutiva (Savelli and Pulga, 2016) consists of training activities with the aim of improving some specific aspects of the reading process, such as phonological analysis, phonemic synthesis and lexical access, in children from six years of age. The App has also the purpose of verifying the potential support that new information technologies can offer to the rehabilitation practice, specifically to the monitoring of performances and to the personalisation of tasks, which can also be continued at home.

In line with the DRC model of reading (Coltheart et al., 2001) and the developmental framework of reading (Frith, 1986), Dislessia Evolutiva allows the construction, automation and integration of the processes that, during child's development, form the reading system. Furthermore, the different tasks can be combined in personalised paths so as to answer to the heterogeneity of individuals' difficulties and to the differences in the stages of acquisition of the reading ability (Table 7).

Table 7. Dyslexia manifestations during the stages of reading skills acquisition (Savelli and Pulga, 2016)

Early stages of acquisition (1st year of Primary School)
● Difficulty and slowness in the acquisition of the alphabetic code and in the application of grapheme-phoneme mappings. ● Limited control on operations of phonemic analysis and synthesis, with errors that grossly alter the phonological structure of the words read. ● Limited or absent lexical access, even when words are read correctly. ● Ability to read, intended as 'recognition', only a limited number of known words.

Subsequent stages (2nd to 4th year of Primary School)
• Gradual acquisition of the alphabetic code and grapheme-phoneme mappings, which are not fully stabilized. • Difficulties may persist in checking more complex orthographic mappings. • Phonemic analysis and synthesis remain difficult and scarcely automated operations. • Lexical access improves, even if it remains slow and limited to the most frequent words.
Final stage (5th year of Primary School and Lower Secondary School)
• Almost complete mastery of the alphabetic code and stabilization of grapheme-phoneme mappings. • Phonemic analysis and synthesis and lexical access begin to automate, at least with the most frequently used words. • Limited access to orthographic lexicon. • Poor integration of decoding and comprehension processes: reading remains difficult.

APPLICATION STRUCTURE

Figure 19. Dislessia Evolutiva home screen (Savelli and Pulga, 2016)

The first time after the installation and after having clicked on the "ENTER" button (Fig. 19), the user chooses between "FAMILY" or "PROFESSIONAL" option, as the proposed activities have been designed considering not only the needs of psychologists, teachers and speech therapists, but also of families who, thanks to the use of pregenerated and guided programs, can make the child exercise on their specific difficulties.
From now on, references will be made to the professional use of the Application, as used for all the research studies, both within schools and with patients.
Once the mode of use is chosen, the user accesses the "WELCOME" screen (Fig. 20) where the sections "A BIT OF SCIENCE" and "START WORKING" are introduced.
The first section consists of an animated video on Developmental Dyslexia, a glossary on the topic, and FAQs that answer the most frequent questions on SLD and dyslexia, as well as a brief introduction about the proposed activities, their applications and aims.

Figure 20. Dislessia Evolutiva welcome screen (Savelli and Pulga, 2016)

In the "START WORKING" section, the user will involve the child in creating their own profile by defining the name and the class and by choosing the guiding character which will accompany them during the activities (Fig. 21). The animated character that guides the user throughout the activities can be considered a gamified element that enhance *immersion* and, therefore, motivation (Hassan and Hamari, 2019; Koivisto and Hamari, 2019).

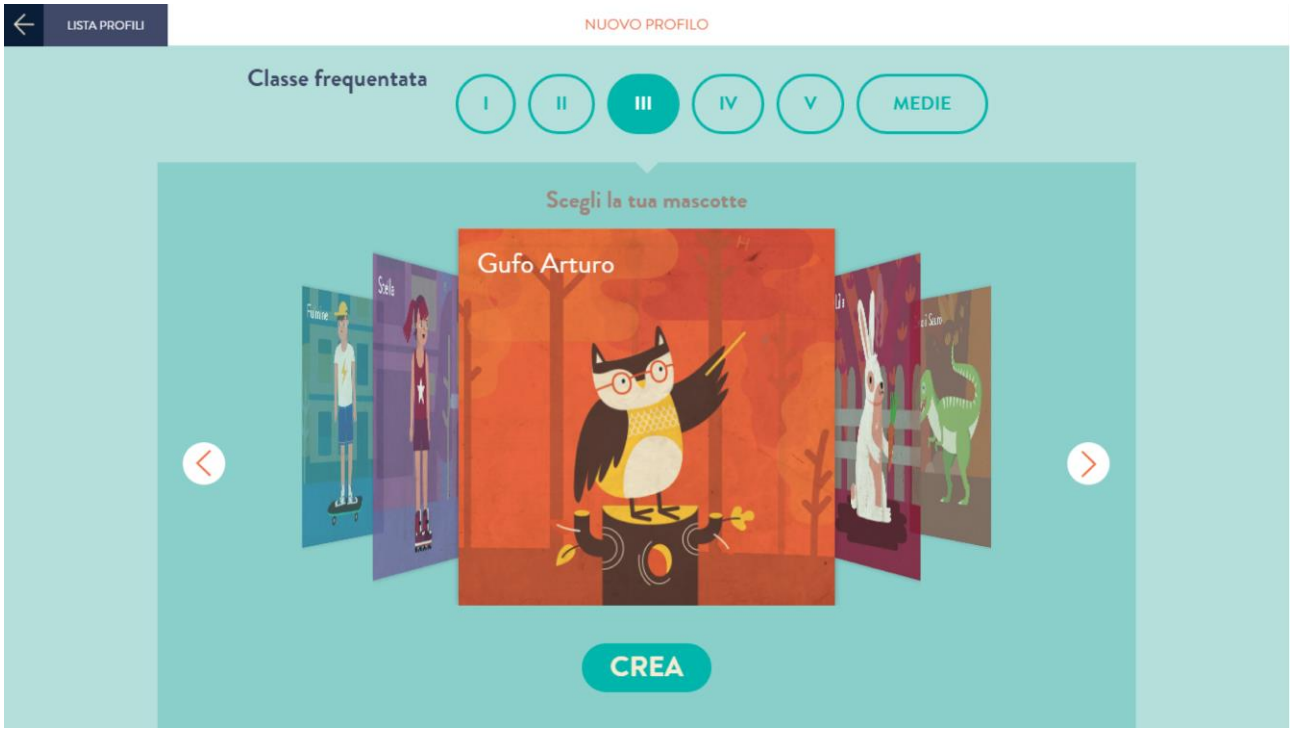

Figure 21. Dislessia Evolutiva profile creation screen (Savelli and Pulga, 2016)

Then, it is possible to proceed to the main screen in which there are, in the lower dark band, the tools menu and, right above in the white band, the activities menu (Fig. 22).
The tools menu, through the "CONFIGURATION" function (Fig. 23), allows to add new users or to modify or delete those already registered, as well as to change the modality from "PROFESSIONAL" to "FAMILY". It also gives the option to activate the "REMOTE FEEDBACK", a spin-off and free Application, available on Google Play and iTunes, which has been designed to facilitate the professional in keeping track of the errors made by the child during those activities that do not require a written answer and, as consequence, do not have an automatic counting.

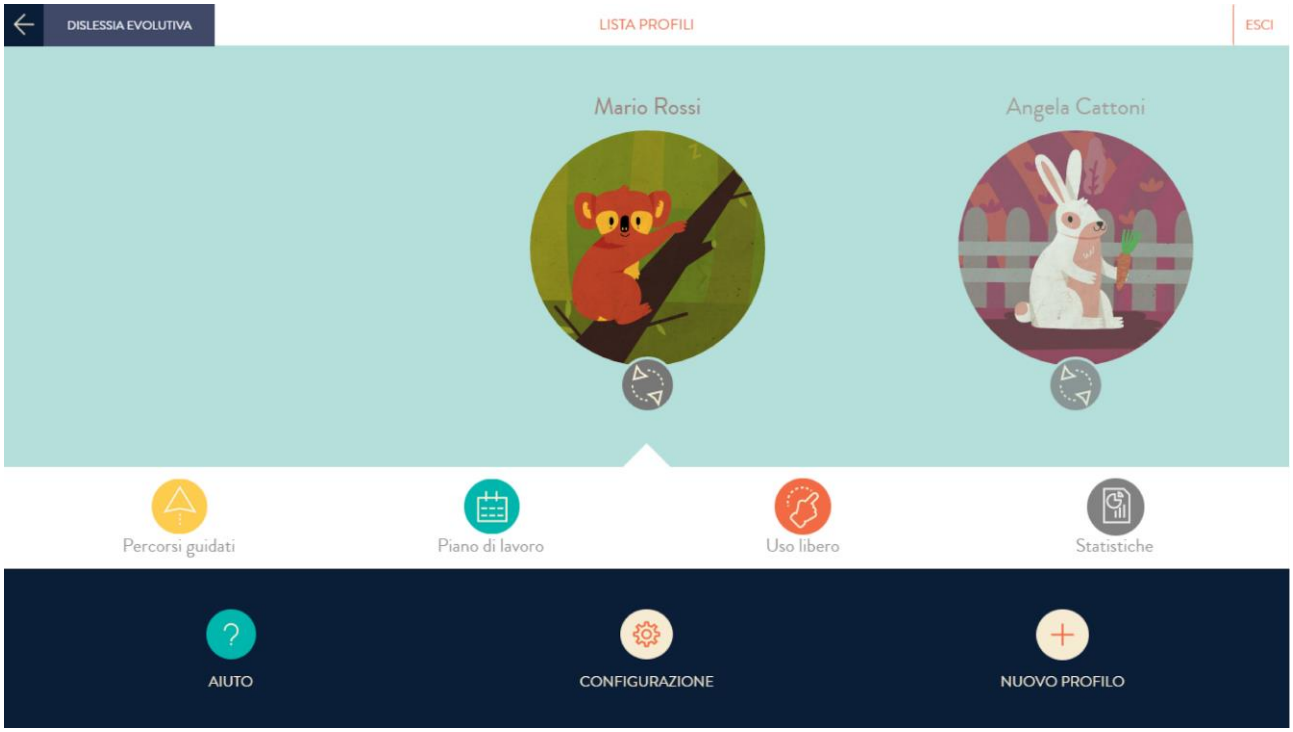

Figure 22. Dislessia Evolutiva main screen (Savelli and Pulga, 2016)

Figure 23. Dislessia Evolutiva configuration screen (Savelli and Pulga, 2016)

The activities menu presents the four main functions of the Application: "GUIDED PROGRAMS", "WORK PLAN", "FREE USE", and "STATISTICS".
The "GUIDED PROGRAMS" (Fig. 24) are pre generated and targeted paths that allow children to work on their specific difficulties. It is a section specifically designed for parents who, by answering a few simple questions, can identify the most suitable program to meet the needs of their child who will be able to start the activities immediately. Each program consists of one or more exercises of different types,

related to four specific aspects on which the child will work, and includes three levels of increasing difficulty.
The activity can be further directed through the Auto Setup, which proposes to choose between four specific aspects on which you want to work with the child (Recognising letters with similar sounds and shapes, Recognising and merging letters or syllables together to compose the words, Recognise and read words and passages correctly and quickly, Recognise and read words with spelling difficulties) and, based on the choice made, select the most suitable paths to intervene on the difficult situation.

Figure 24. Dislessia Evolutiva guided programs screen (Savelli and Pulga, 2016)

The "WORK PLAN" (Fig. 25) consists of a calendar where the professional can schedule the meetings with the children and set the activities that they will execute, also at home. With the "EDIT" button the professional can set, for each day of the week, the exercises, and related parameters, that the child must perform. Furthermore, by synchronising the device with that of the family (using the "SYNC" button), both the parents and the professional can simultaneously keep track of the activities done.

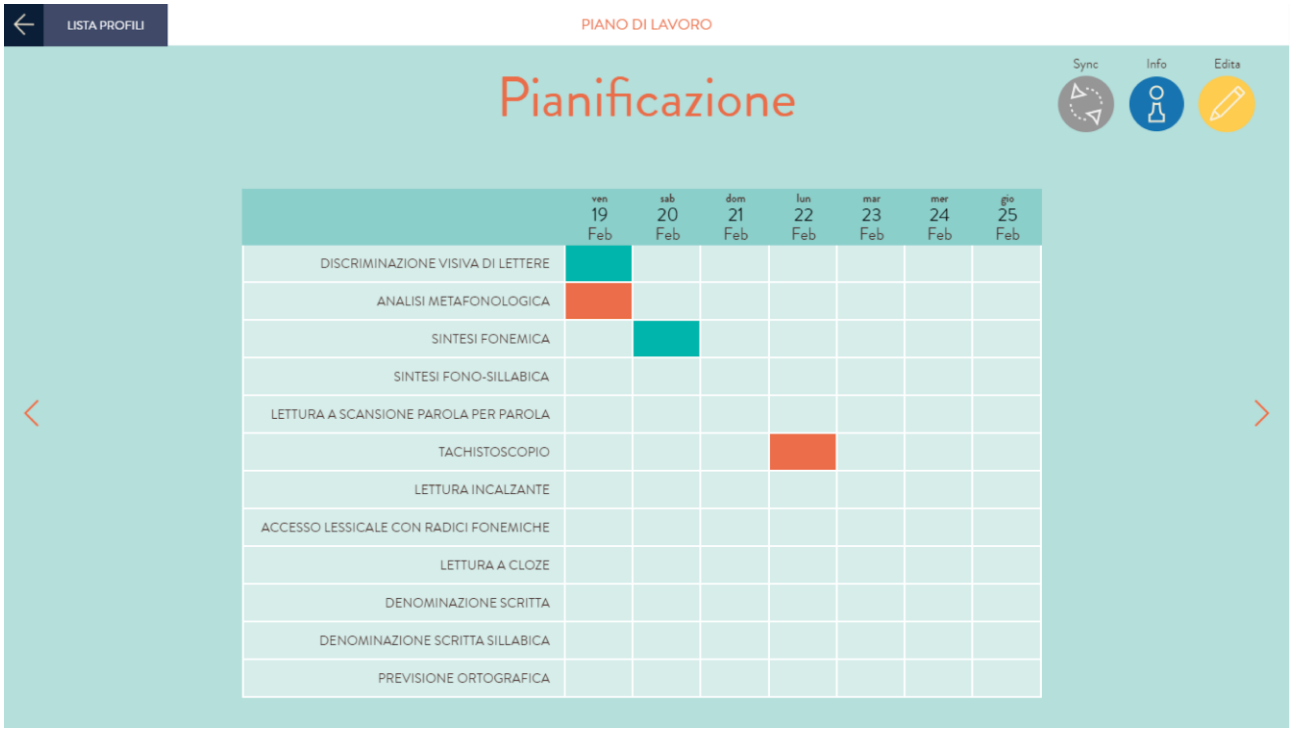

Figure 25. Dislessia Evolutiva work plan screen (Savelli and Pulga, 2016)

The "FREE USE" (Fig. 26) mode allows the professional to freely navigate between all the activities and to build a personalized intervention based on the child's specific difficulties and needs. For each exercise it is also possible to customise some parameters (word length, spelling complexity, number of clozes, etc.) to set the optimal level of facilitation for the task. Once all the parameters are set and saved, the child is asked to start the game, when they feel ready, by clicking on the screen.

Such personalisation of the profile and the customisation of tasks and related parameters have the twofold objective of offering the child an experience as suit as possible to their specificities (preferences, skills, needs, and objectives), as well as enhancing motivation even more during activities thanks to a deeper *immersion*.

At the end of each activity, a "SUMMARY" screen shows the time taken by the child to perform the exercise and any errors made. From this same screen it is then possible to choose whether to restart the exercise, modify its parameters or return to the list of activities.

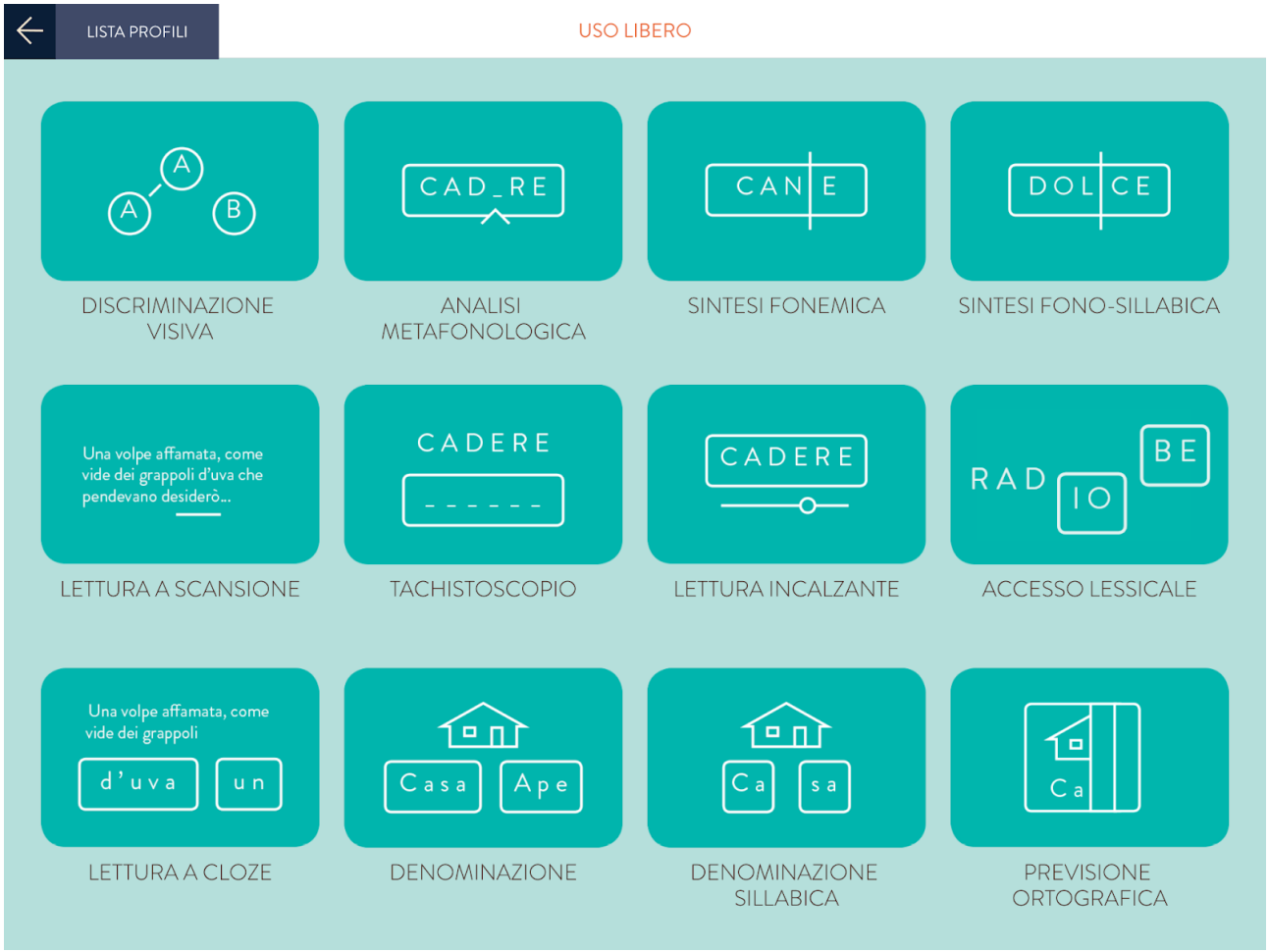

Figure 26. Dislessia Evolutiva free use screen, with all the activities (Savelli and Pulga, 2016)

The exercises are grouped by training objectives, based on the various developmental stages of reading-writing skill acquisition (Table 8).

Table 8. Dislessia Evolutiva structure and objectives (Savelli and Pulga, 2016)

SKILL BUILDING		
Objective	**Difficulty description**	**Activity**
Acquisition (and stabilisation) of the alphabetic code and of the grapheme-phoneme "mapping" system	Difficulty in knowing the basic elements of the alphabet (letters), in recognising graphemes and sign-sound correspondences.	*Discriminazione visiva di lettere* [Visual discrimination of letters]
Construction of grapheme-phoneme conversion operations	Difficulty in representing the orthographic and phonological structure of words.	*Analisi metafonologica* [Metaphonological analysis]
	Difficulty in representing the syllabic structure of words.	*Denominazione sillabica* [Syllabic denomination]

Construction (and stabilization) of the basic operations of phonemic analysis and synthesis	Difficulty in executing the phonemic fusion process.	*Sintesi fonemica - modalità automatica* [Phonemic synthesis - automatic mode] *Previsione ortografica* [Orthographic prediction]

SKILL AUTOMATION

Objective	Difficulty description	Activity
Automation of orthographic analysis operations	Difficulty in segmenting the word into syllabic constituents and in executing the syllabic fusion process.	*Sintesi fono-sillabica* [Phono-syllabic synthesis]
Automation of lexical access processes	Difficulty in lexical access, that is the ability to quickly retrieve words that begin with a specific sound, from the mental dictionary (phonological lexicon).	*Sintesi fonemica - modalità manuale* [Phonemic synthesis - manual mode]
	Difficulty in lexical access, that is the ability to quickly retrieve words that begin with a specific morphemic root, from the mental dictionary (phonological lexicon).	*Accesso lessicale* [Lexical access]
Automation of orthographic analysis operations Automation of grapheme-phoneme conversion operations Visual recognition and (rapid) access processes to the orthographic lexicon	Difficulty in quickly recognising the orthographic structure of syllables and words.	*Tachistoscopio* [Tachistoscope] *Lettura incalzante* [Fast reading]

DEVELOPMENT OF TOP-DOWN STRATEGIES

Objective	Difficulty description	Activity
Use of the context and of the processes of lexical anticipation and integration between	Difficulty in quickly recognising the structure of words and the use of semantic anticipation	*Lettura a scansione* [Scan reading]

decoding and comprehension	processes.	
	Difficulty in using the processes of semantic anticipation and integration between decoding and comprehension.	*Lettura a cloze* [Cloze reading]

DEVELOPMENT OF COMPREHENSION PROCESSES AND WRITING SKILLS		
Objective	**Difficulty description**	**Activity**
Lexical comprehension	Difficulty in understanding written words.	*Denominazione - scelta multipla* [Naming - multiple choice mode]
Orthographic skills	Difficulty in recovering the correct orthographic structure of the word in a writing task starting from an image.	*Denominazione - modalità scritta* [Naming - written mode]

Within the "STATISTICS" section (Fig. 27) the professional can check the child's progress and monitor their improvements, based on the exercises performed, through an intuitive summary graph that shows the time taken and the errors made by the user.

Figure 27. Dislessia Evolutiva statistics screen (Savelli and Pulga, 2016)

Both the results, at the end of each exercise, and the statistics that the professional can present to parents or children themselves, allow to check users' progression over time and to confront it with others'. These features allow either immediate feedback or continuous monitoring of child's *achievements* and, in the short

and long term, can help increase their motivation for better and longer lasting learning results (Hassan and Hamari, 2019; Koivisto and Hamari, 2019; Sailer et al., 2014; Sailer et al., 2017; Taylor et al., 2014; Xi and Hamari, 2019).

APPLICATION ACTIVITIES

The intervention program can be designed to have a progressively increasing difficulty, so to stimulate the sense of *achievement*, and the Application offers some elements of support and help (i.e., prompts, suggestions, "lifebelts", progression numbers to know at what point of the activity one has arrived, etc.) in order to avoid situations of frustration and stress, which can induce the user to abandon the activity started. Moreover, audio-visual feedback represents a reinforcement related to the performance and also contribute to increase *immersion* for the user.
The following subsections briefly present the Application activities, providing information in terms of their cognitive aims and their mechanics.

Visual discrimination of letters

Children with SLD and, specifically, with Developmental Dyslexia could have difficulties in encoding the visual-spatial attributes of letters and words and then, in recognising similar graphemes (i.e., 'b' and 'd'). This exercise aims at improving the visual coding process and thus the discrimination of similar graphemes.
The practitioner has to specify, among all alphabet letters, those two that are object of discrimination, as well as some other parameters (i.e., font type, upper- or lowercase; exposure time of the target letter, scanning mode). The Application then randomically presents one of the two pre-selected letters (the target letter) and, after the exposure time, both letters appear at the screen bottom. The child's task is to recognise and choose the target letter (Fig. 28).

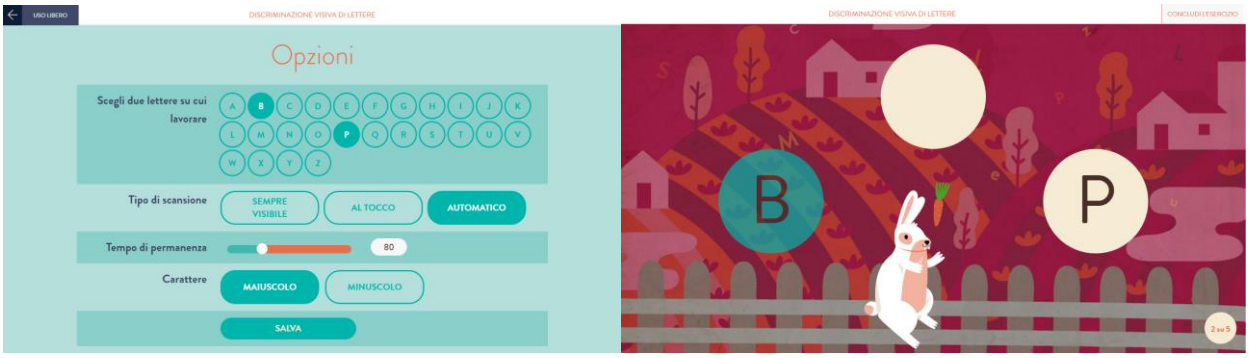

Figure 28. Dislessia Evolutiva - "Visual discrimination of letters" options and exercise screen (Savelli and Pulga, 2016)

Metaphonological analysis

The difficulty in phonological processing is typical in Developmental Dyslexia and has a crucial impact on metaphonological skills, that is the ability to explicitly reflect and manipulate the phonological structure of words.
This exercise aims at promoting the process of awareness of words' phonological structure through the sequential analysis of their orthographic structure. The practitioner chooses the dictionary (full, partial,

most used words) which words are taken from, then the child is presented with a sequence of incomplete words that they have to complete by typing the missing letter (Fig. 29).
For some children, the task could be difficult. Therefore, the Application provides the opportunity, for the child, to choose the correct missing letter among three others, thus restricting the decision-making field and allowing to verify the different completion outcomes. For this exercise, speech synthesis is also available.

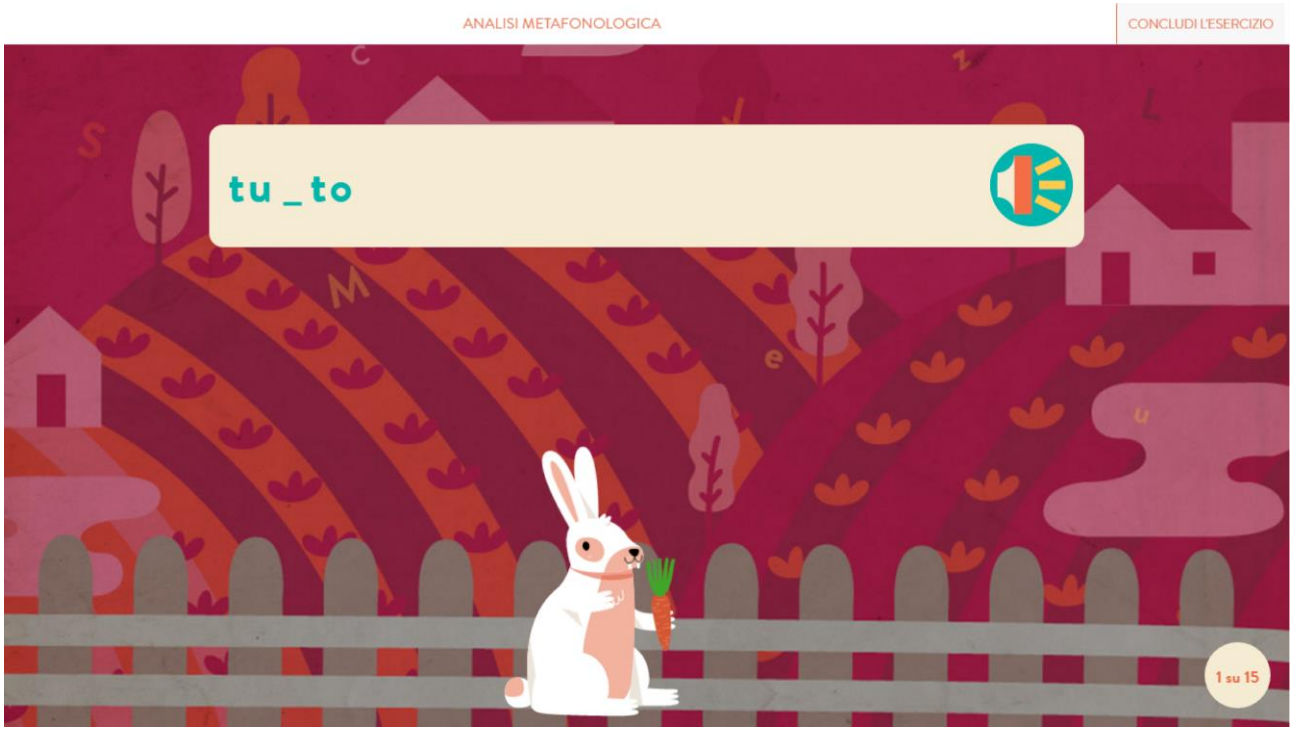

Figure 29. Dislessia Evolutiva - "Metaphonological analysis" exercise screen (Savelli and Pulga, 2016)

Phonemic synthesis

One of the main difficulties that children with Developmental Dyslexia encounter at an early stage of reading acquisition is assembling the sounds, resulting from grapheme-phoneme conversion, to form words.
This exercise aims at encouraging both the development and automation of the online phonemic synthesis process, and the process of lexical access, thanks to a systematic forecasting strategy based on phonemic clues.
In relation to the phonemic synthesis, the Application generates and presents in sequence the single letters that compose a word, and the child has to progressively assemble the presented letters, until the entire word is pronounced, thus 'recalculating' the word phonological structure in real time.
As for the lexical access, by setting the manual mode of letters scanning, the child is asked to guess the word at each shown letter, by continually remodelling their hypothesis. First attempts are most probably casual, but after some clues have been given, access to a certain lexical unit is almost forced.
Also, for this activity, a preliminary selection of some parameters is required (i.e., scanning mode; type of dictionary; number of letters; font type; Fig. 30).

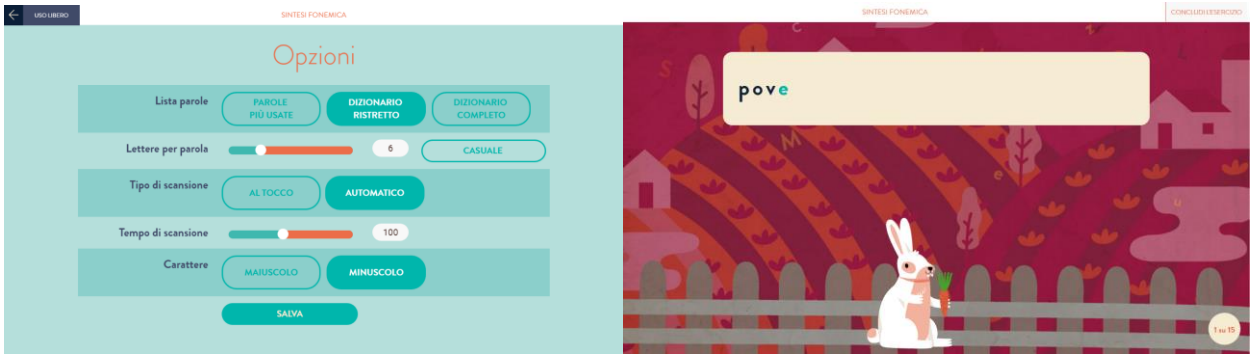

Figure 30. Dislessia Evolutiva - "Phonemic synthesis" options and exercise screen (Savelli and Pulga, 2016)

Phono-syllabic synthesis

Once the child has practiced the combination of sounds (phonemic synthesis) and is familiar with various types of syllabic units, the subsequent natural step, that is also necessary for a fluent reading, comes with the phono-syllabic synthesis.
The practitioner sets several parameters (i.e., syllables number; scanning mode; scanning speed), thereafter the child proceeds to the online assembly of the phonological structure of the word (Fig. 31).

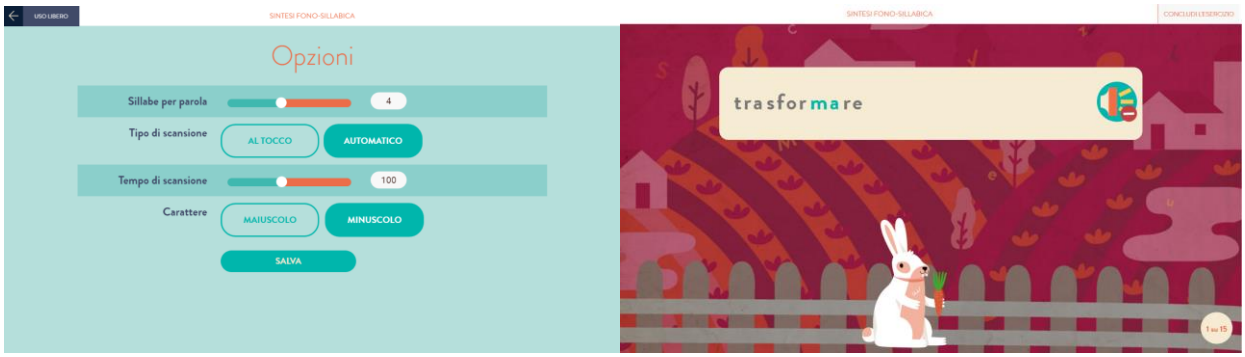

Figure 31. Dislessia Evolutiva - "Phono-syllabic synthesis" options and exercise screen (Savelli and Pulga, 2016)

Scan reading

Reading a text is a complex activity in which several processes are involved. Therefore, the identification of the deficient function is difficult. The reading of a text, compared to the reading of single words, is greatly helped by contextual anticipation processes, and, furthermore, children with Developmental Dyslexia can have difficulties at an attentional and visual perceptual level, together with those related to the decoding process.
In order to control the role of such factors, the exercise presents both a manual and an automatic mode of showing the text word by word (Fig. 32). The texts are divided according to the age group of the children to whom they are addressed. During the activity, it is also possible to activate or deactivate the speech synthesis.

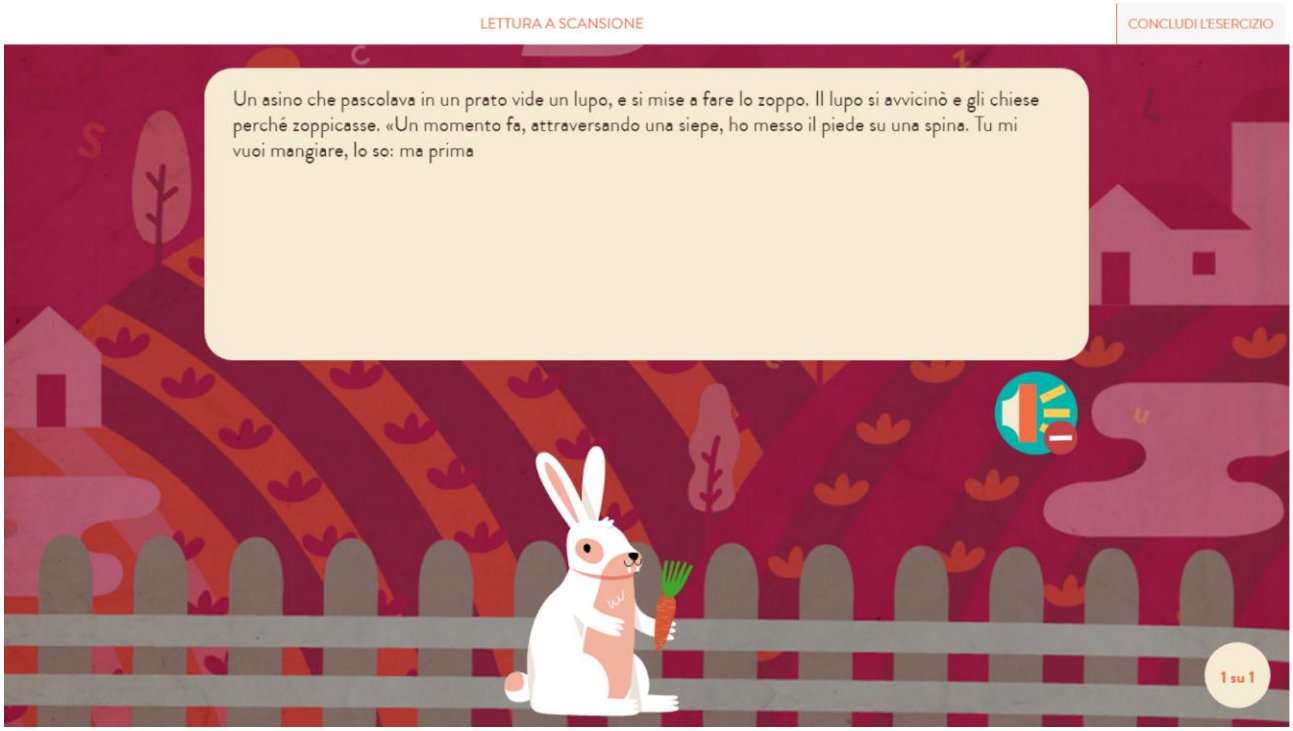

Figure 32. Dislessia Evolutiva - "Scan reading" exercise screen (Savelli and Pulga, 2016)

Tachistoscope

This exercise aims at encouraging the visual processing operations that lead to a fast recognition of words. The word is presented with a short, pre-set, or dynamic, time of exposure. Other parameters are type of dictionary (letters, syllables, non-words, words of various frequency), orthographic complexity of words, number of letters, and font type (upper- or lowercase).

The child has to recognise the presented word and to write it correctly right after (Fig. 33). In order to facilitate the task, the Application gives the opportunity to see again the target word, for the same exposure time, and to have the next letter suggested by the software. It is important to highlight the fact that this exercise, originally designed to enhance the visual recognition process, is also useful for improving orthographic correctness in writing.

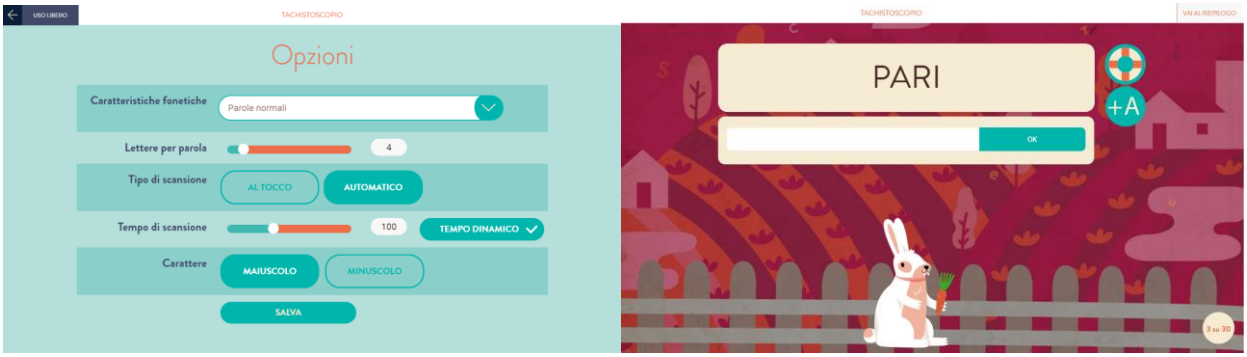

Figure 33. Dislessia Evolutiva - "Tachistoscope" options and exercise screen (Savelli and Pulga, 2016)

Fast reading

This exercise aims at facilitating the automation of the decoding process and of the fast recognition of sub-lexical (syllable) or lexical (word) units through the sequential presentation of lists graded by difficulty.
The type of answer given by the child can be either oral, in which case it is also necessary setting the scanning time, or written (Fig. 34).

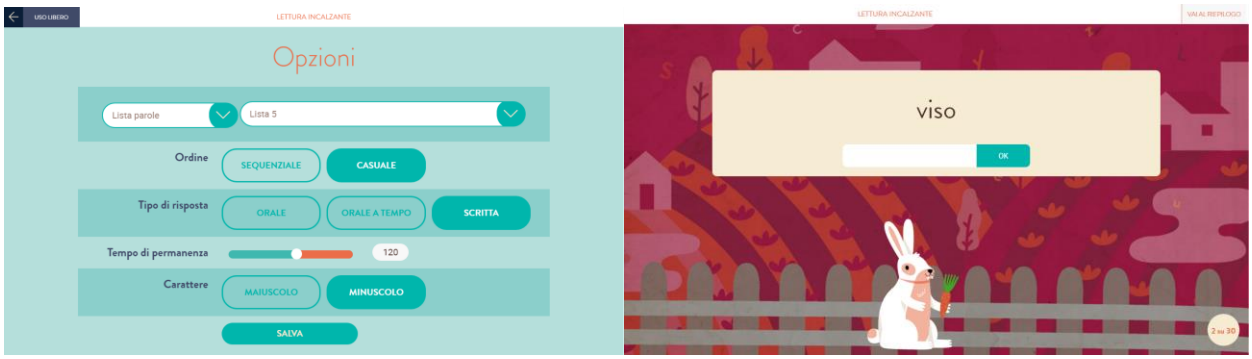

Figure 34. Dislessia Evolutiva - "Fast reading" options and exercise screen (Savelli and Pulga, 2016)

Lexical access

This exercise is aimed at showing the existence of morphemic roots in words and at favouring their use in word recognition and facilitating the processes of 'orthographic' lexical access, which can be difficult for children with Developmental Dyslexia also at an older age as they often struggle in going beyond the alphabetic stage of reading.
Starting from a chosen morphemic root, the Application generates a series of possible word completions both correct and incorrect. The child has to identify, in the shortest possible time, all the graphemic options that correctly complete the morphemic root and that form an existing word (Fig. 35).

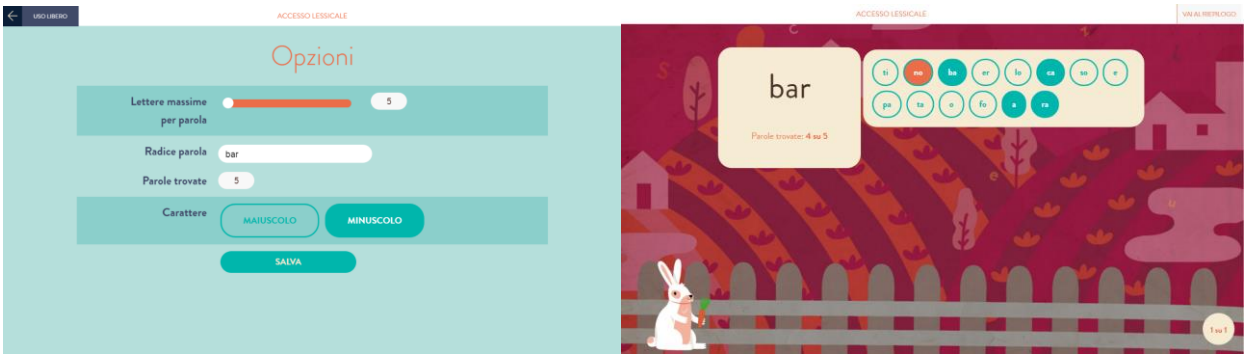

Figure 35. Dislessia Evolutiva - "Lexical access" options and exercise screen (Savelli and Pulga, 2016)

Cloze reading

The reading of a text, compared to that of single words, rests extensively on the process of 'contextual anticipation' that allows to 'skip' the actual reading of some words, whose presence can be inferred based on the online sentence understanding. In fact, this reading mode is not based on pure decoding, but it is more likely a 'completion' (cloze) strategy based on contextual clues.

The extensive use of anticipation strategies determines the speed and fluency of reading. In children with Developmental Dyslexia, the use of these strategies can manifest incredibly early, even before having developed sufficient decoding skills, and does not integrate with the decoding, thus leading to an inefficient and even counterproductive guessing reading process.
This exercise aims at promoting the ability to read, at a textual level, by using anticipation strategies through contextual clues. Once the text has been chosen, the Application presents the first five words and, in a side window, some possible options; only one option corresponds to the target word, the others are distractors (Fig. 36). If the options are limited to two, a certain reading fluency is guaranteed; by increasing the number of options, instead, the decision-making process becomes more complex, with a consequent slowdown in fluency.

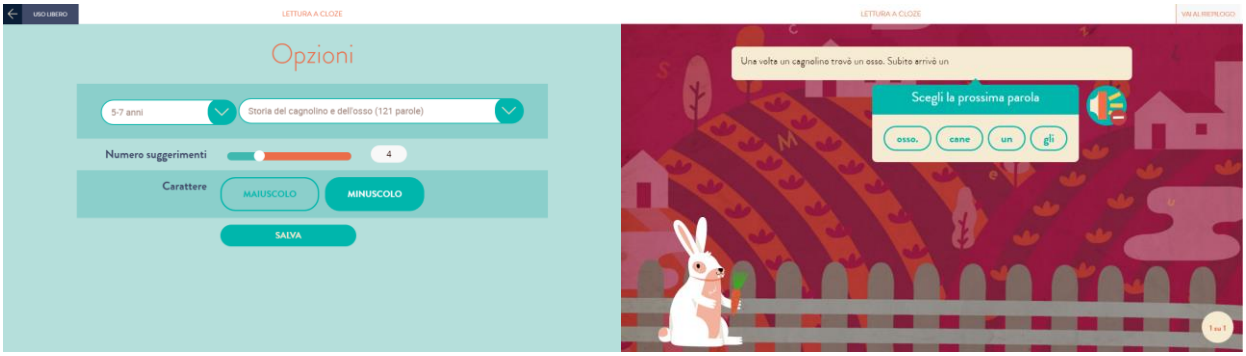

Figure 36. Dislessia Evolutiva - "Cloze reading" options and exercise screen (Savelli and Pulga, 2016)

Naming

This exercise aims at improving the ability to write and recover the correct orthographic structure of words. The Application presents images randomly chosen from one semantic category (i.e., animals, domestic elements, food, etc.). The child must write the name of the object shown in the image.
Writing can be assisted by speech synthesis, which gives online phonetic feedback, and facilitated by suggestions of the subsequent necessary letter that completes the word. It is also possible to select the "multiple choice" option rather than the "written" one as the type of answer required. In this case, four words are shown next to each image, only one of which is correct (Fig. 37).

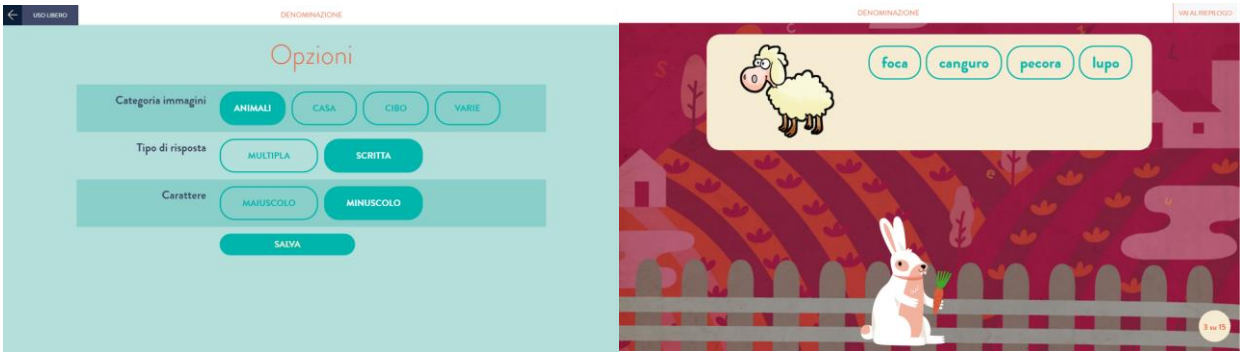

Figure 37. Dislessia Evolutiva - "Naming" options and exercise screen (Savelli and Pulga, 2016)

Syllabic naming

Syllables are the smallest units of language that we can perceive and produce alone. At the simplest level, syllables are composed of a consonant sound followed by a vowel sound (CV structure). Many preschool

children can make a syllabic segmentation of words based on their phonological structure, in a natural and spontaneous way and without a previous exposure to any formal written code teaching. It is therefore useful, at an early stage of teaching, to introduce the child to the syllabic structure of words and their graphemic representation (phono-syllabic method). Children are thus facilitated in manipulating (segmenting) the sounds of language, especially if they have cognitive and/or linguistic difficulties, and in building a rule system of correspondence between signs and sounds.
The exercise presents an image, chosen from several semantic categories, and, next to it, the syllabic segments that are used to compose the word are shown in a random order. The child is asked to recompose the word by ordering the syllabic segments in the correct sequence. If the choice is wrong, the syllable remains in its original position and the error is also signalled by acoustic feedback. It is possible to graduate the level of difficulty of the exercises by setting the maximum number of syllables that make up the word (from two to six), and the possible presence of distractors (Fig. 38).

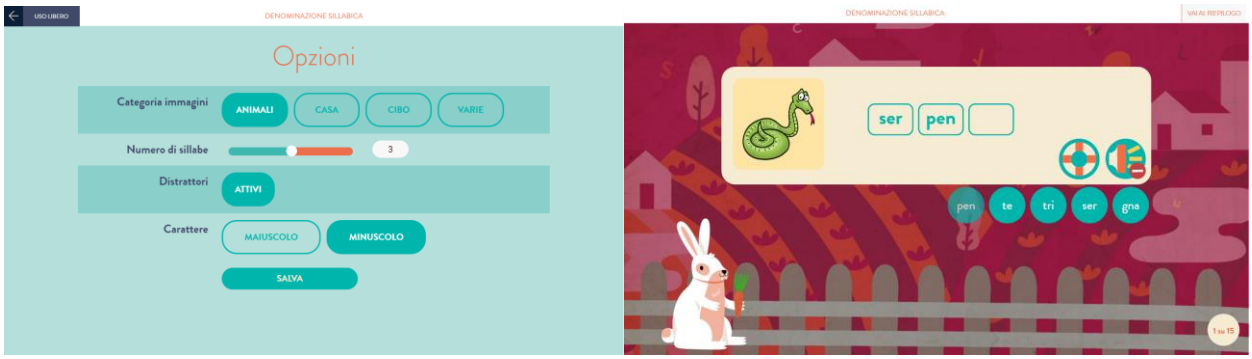

Figure 38. Dislessia Evolutiva - "Syllabic naming" options and exercise screen (Savelli and Pulga, 2016)

Orthographic prediction

This exercise aims at encouraging the development of online phonemic synthesis processes, also making use of an iconic aid, and at stimulating lexical access processes with the combined use of partial orthographic and iconic information.
The Application presents an image, chosen from several semantic categories, partially covered by a vertical bar grid (the number of bars is equal to the number of letters that compose the target word). By clicking on each bar, from left to right, the child can progressively discover the image, until it is completely revealed. The child is, though, asked to recognise and write the word beforehand, by using both orthographic and iconic clues (Fig. 39).

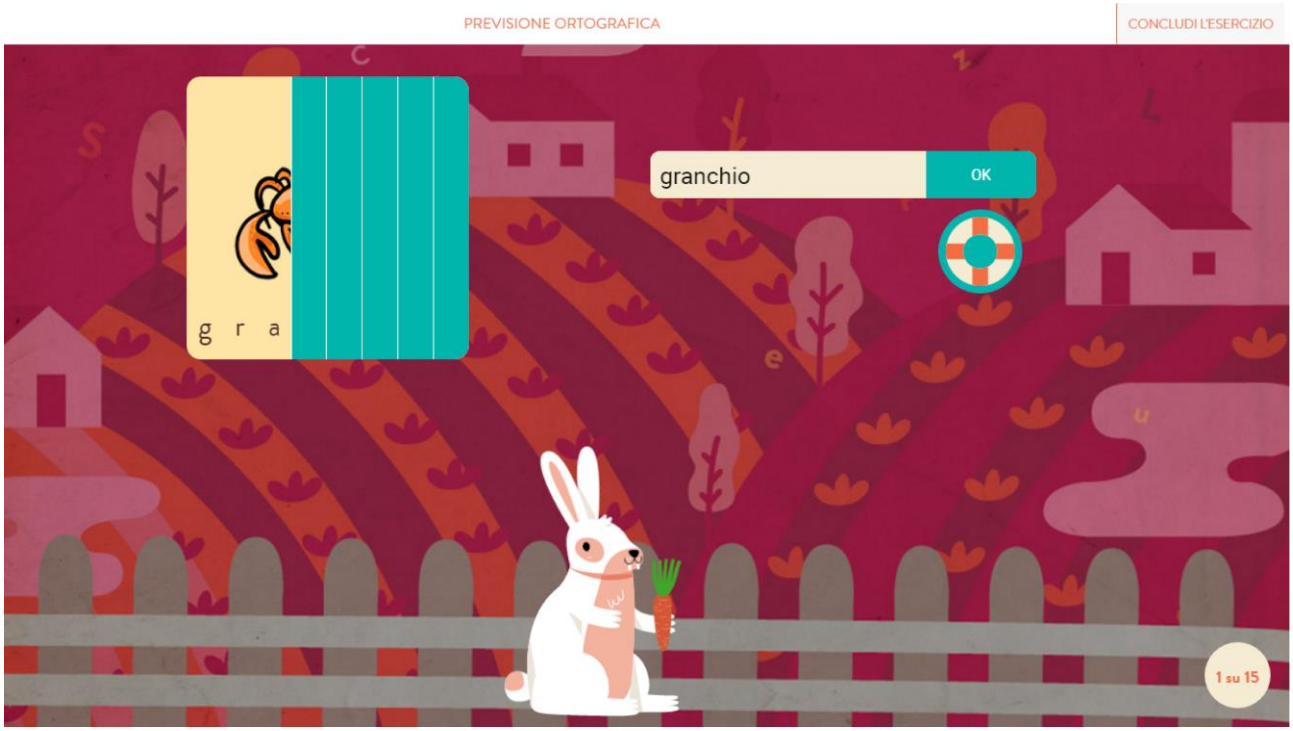

Figure 39. Dislessia Evolutiva - "Orthographic prediction" exercise screen (Savelli and Pulga, 2016)

3.4.4.8 *Recupero in Ortografia*

(Ferraboschi and Meini, 2016)

The Application Recupero in Ortografia (Ferraboschi and Meini, 2016) consists of training activities that aim at recovering and improving orthographic correctness skills in primary and low secondary school children. It has been designed in accordance with Uta Frith's (Frith, 1986) developmental framework of writing.

Frith's model highlights how the crucial phase of any writing system based on alphabetic rules is, precisely, the alphabetic one, that is the phase in which children first recognise that the sound of a word can be broken down into smaller parts (syllables and phonemes) and, subsequently, they associate them with the corresponding graphemes. The orthographic phase, as already mentioned, is a phase of improvement of the alphabetical one and anticipates the lexical phase as it fixes the exceptions to the rule "one phoneme = one grapheme" and makes the words recognition and writing faster.

Based on this model, Tressoldi and Cornoldi proposed the classification of the various types of errors present in the Italian language (Tressoldi and Cornoldi, 1991), dividing them into three main categories: phonological errors, non-phonological errors, and errors in the use of accents and double letters. If the acquisition of the alphabetic phase is deficient, the child will make phonological errors, while a compromised acquisition in the lexical phase will lead the child to make non-phonological errors. The third category has been added to include all other possible misspellings.

The various Application activities have thus been designed starting from these assumptions. They have the aim of helping the child in the acquisition of error awareness and in controlling the automatic writing processes.

APPLICATION STRUCTURE

Figure 40. Recupero in Ortografia home screen (Ferraboschi and Merini, 2016)

The first time after the installation and after having clicked on the "ENTER" button (Fig. 40), the user accesses the "WELCOME" screen where the sections "A BIT OF SCIENCE" and "START WORKING" are introduced.

The first section presents the most frequently asked questions and a glossary, as well as some suggestions on how to best use the activities to improve writing.

By selecting the second section, instead, it is possible to use the Application in the classroom on the interactive whiteboard (IWB), and to freely access the proposed activities; otherwise, it is possible, for the user, to access an individual section in which they can create their own personal profile by entering the name, the attended class and the avatar (Fig. 41). This is just one of several gamified elements of *immersion* that can increase user's motivation, as demonstrated in recent studies (Hassan and Hamari, 2019; Koivisto and Hamari; 2019).

Moreover, for each profile it is possible to check the statistics, create new training programs, continue those already started or use pre generated ones. The individualised option was chosen for the purposes of the current research.

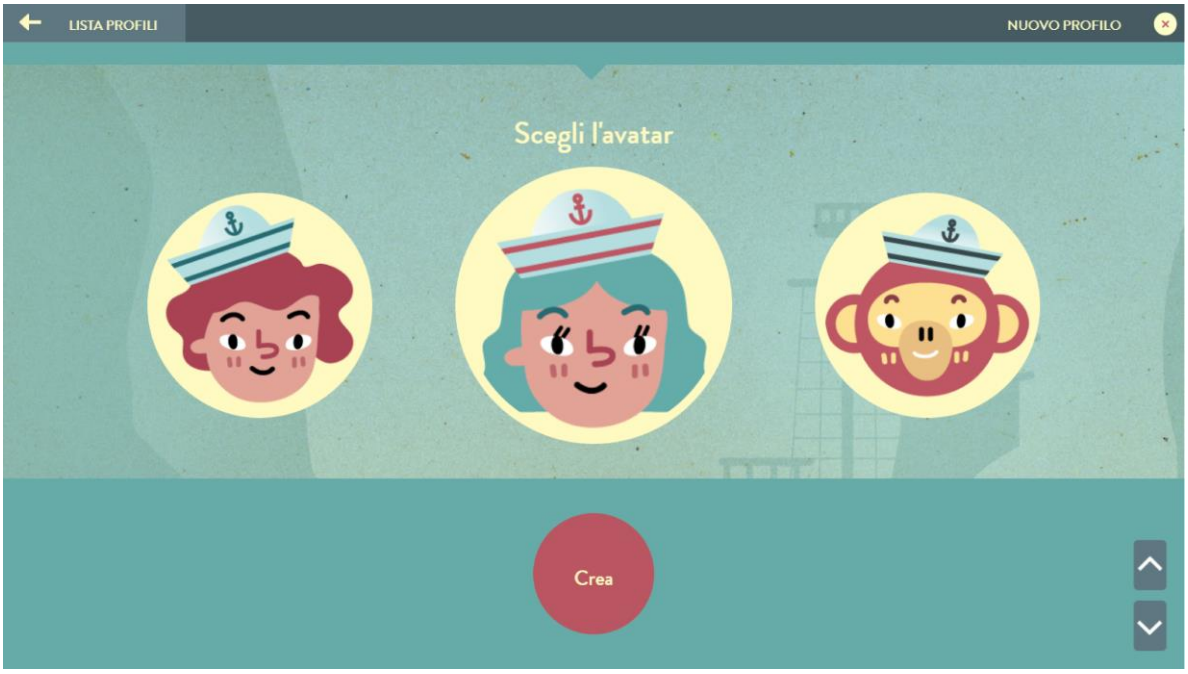

Figure 41. Recupero in Ortografia profile creation screen (Ferraboschi and Meini, 2016)

At the time of creating the training program, the user chooses its name and the related exercises, in number of 5, 10 or 20. Profile and training program customisation allows to adjust the activities based on user's preferences, needs, skills and objectives. For the purposes of the current research, each training program, that is a treasure map in accordance with the Application narration and main theme, has been created with professional's supervision. The treasure map consists of a series of exercises, numbered in progressive order (Fig. 42).

Figure 42. Recupero in Ortografia treasure map screen (Ferraboschi and Meini, 2016)

As the exercises are completed, the child proceeds on to the next one, thus getting closer and closer to the end of the program and, therefore, to the treasure. In addition, for each task completed in a sufficiently correct way, the Application gratifies the child with a virtual trophy and assigns them a maximum of five dots, in relation to the percentage of errors made (Fig. 43). The user can always check their results and repeat the activity to improve. Furthermore, every five completed exercises, the user level increases, progressively passing from Ship's Boy to Captain and the appearance of the chosen avatar changes accordingly. The user can always see their trophies and avatar in the treasures screen (Fig. 44). The treasure map, as well as scores and trophies related to user's performance, helps give a sense of progression and *achievement* to the game, also increasing child's motivation.

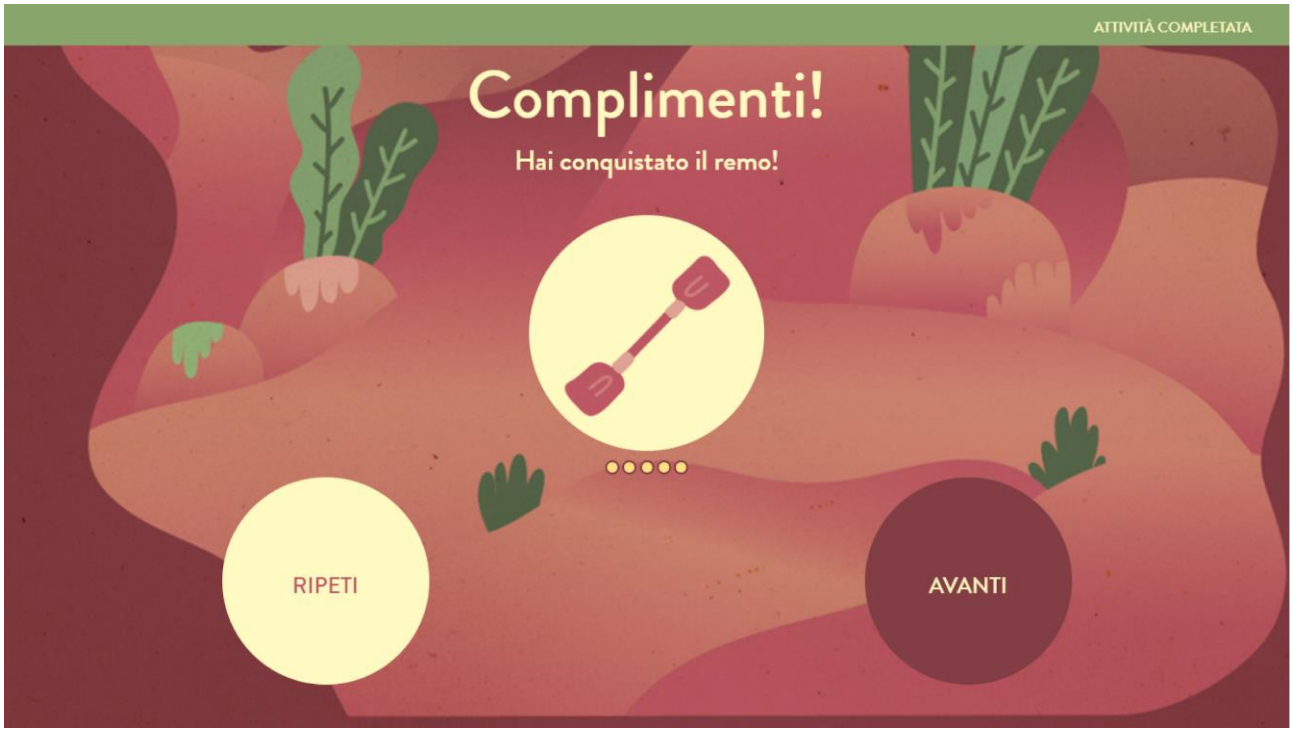

Figure 43. Recupero in Ortografia feedback screen (Ferraboschi and Meini, 2016)

Figure 44. Recupero in Ortografia treasures screen (Ferraboschi and Meini, 2016)

During each activity, an animated character, that is the Pirate Captain, is displayed on the screen and explains the task objective, as well as providing visual and auditory feedback, enhancing motivation through both *immersion* and *progression* of the user. The parrot, on the other hand, provides suggestions and advice regarding the specific type of error being practiced. Taken together, these gamified elements represent a reinforcement related to the performance

APPLICATION ACTIVITIES

The exercises are grouped into three categories, based on the type of errors reported most frequently by children with orthographic difficulties. The following subsections briefly present each category and also provide information in terms of their cognitive aims of related exercises.

Phonological errors

These are errors in which the relationship between phoneme and grapheme is not respected, then they are related to the omission or addition of letters or syllables (e.g., *taolo* instead of *tavolo*), inversions (e.g., *il* instead of *li*), exchange of graphemes (e.g., *brina* instead of *prima*) and the use of an incorrect grapheme (e.g., *agi* instead of *aghi*).
As for the activities related to the omission or addition of letters, the child has to conduct a correct phonetic analysis of words. The Application aims to make the child acquire phonemic awareness, that is the ability to recognise the phonemes that compose words in order not to omit or add any less or more while writing. In the exercises, the child has to name, by writing, the figures presented or to search for errors in sentences where phonemes have been added or deleted.
Specifically, the exercises are: "Parole nelle caselle" [Words in boxes], "Parole simili, disegni diversi" [Similar words, different images], "Scrivere i nomi delle figure" [Write figures names], "Le definizioni del cruciverba" [Crossword], "Riordino lettere" [Rearrange letters], and "Frasi con errori" [Sentences with errors] (Fig. 45).

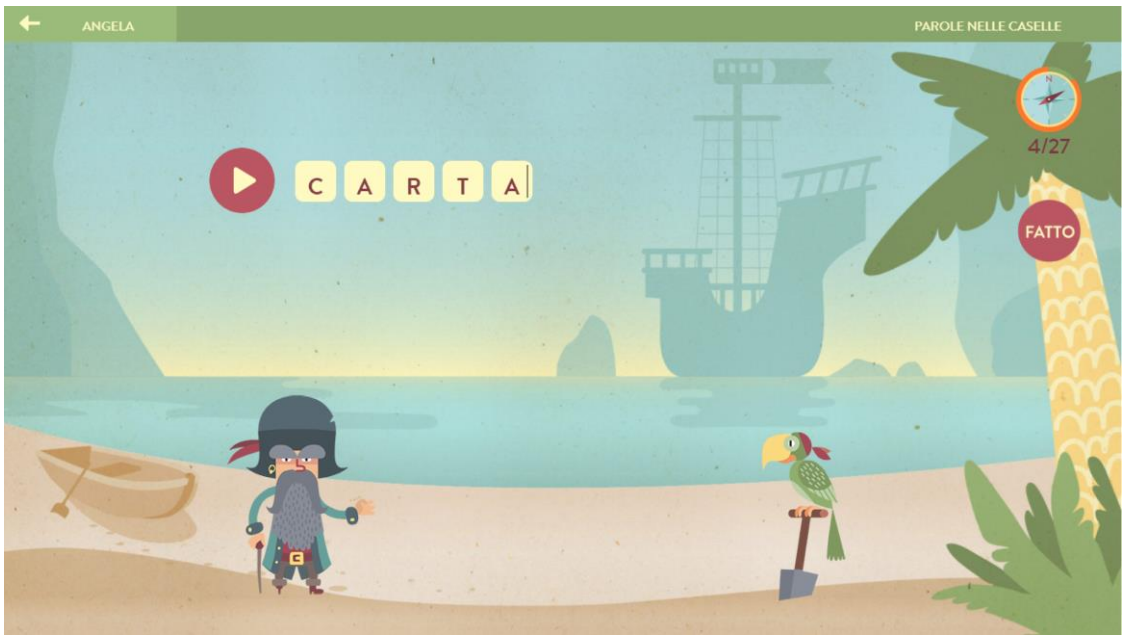

Figure 45. Recupero in Ortografia - "Parole nelle caselle" exercise screen (Ferraboschi and Meini, 2016)

As can be seen in Fig. 45, also this Application shows progression numbers, accompanied by a compass, that allow the user to always know where, within the activity, they are.
The second type of error concerns the inversion of the letters that form syllables and requires a training simultaneously articulated on two levels, that are the phonological analysis and the visual analysis of words' global structure. Therefore, the activities favour reflections on the order within the structure, verify the spatial-temporal organization skills and allow to analyse the global conformation of syllables or words.

Specifically, the exercises are: “Ordine spaziale delle figure” [Spatial order of figures], “Riprodurre sequenze di lettere” [Reproduce sequences of letter], “Ricerca di UN/CAR/BURN tra lettere” [Search for UN/CAR/BURN among letters], “Ordine temporale delle azioni” [Chronological order of actions], “Ascolto di parole e loro ordine temporale” [Words and temporal order], and “Frasi con errori” [Sentences with errors] (Fig. 46).

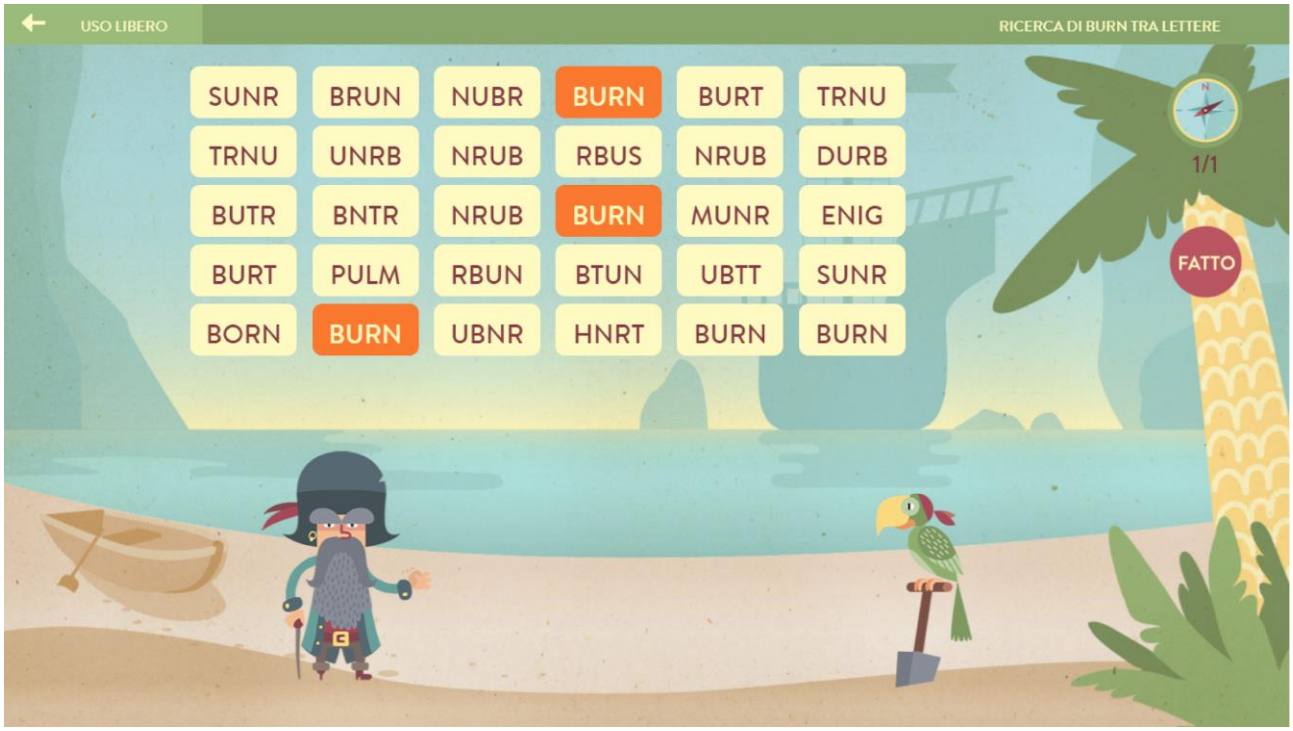

Figure 46. Recupero in Ortografia - “Ricerca di BURN tra le lettere” exercise screen (Ferraboschi and Meini, 2016)

The objective of the section on the exchange of graphemes is to train the child to discriminate and correctly write acoustically similar phonemes, such as F-V, D-T, P-B, C-G. The proposed activities essentially aim at developing or enhancing perceptual-auditory skills (auditory analysis and discrimination) of phonological competence and phonemic awareness for the distinction of acoustically similar phonemes and favouring and stabilizing the phoneme-grapheme association using facilitators at a visual level.

Specifically, the exercises are: “Riflessione sui suoni F e V/D e T/P e B” [Reflection on sounds F and V/D and T/P and B], “Ascolto di parole con F/T/P iniziale” [Listen to words starting with F/T/P], “Figure con F/T/P iniziale” [Figures starting with F/T/P, “Figure che contengono F/T/P” [Figures containing F/T/P], “Ascolto di parole che contengono F/T/P” [Listen to words containing F/T/P], “Ricerca di F/T/P tra lettere” [Search for F/T/P among letters], “Coppie di parole simili” [Pairs of similar words], “Scelta della parola corretta” [Choose the correct word], “Completamento di parole in frasi” [Complete words in sentences] (Fig. 47).

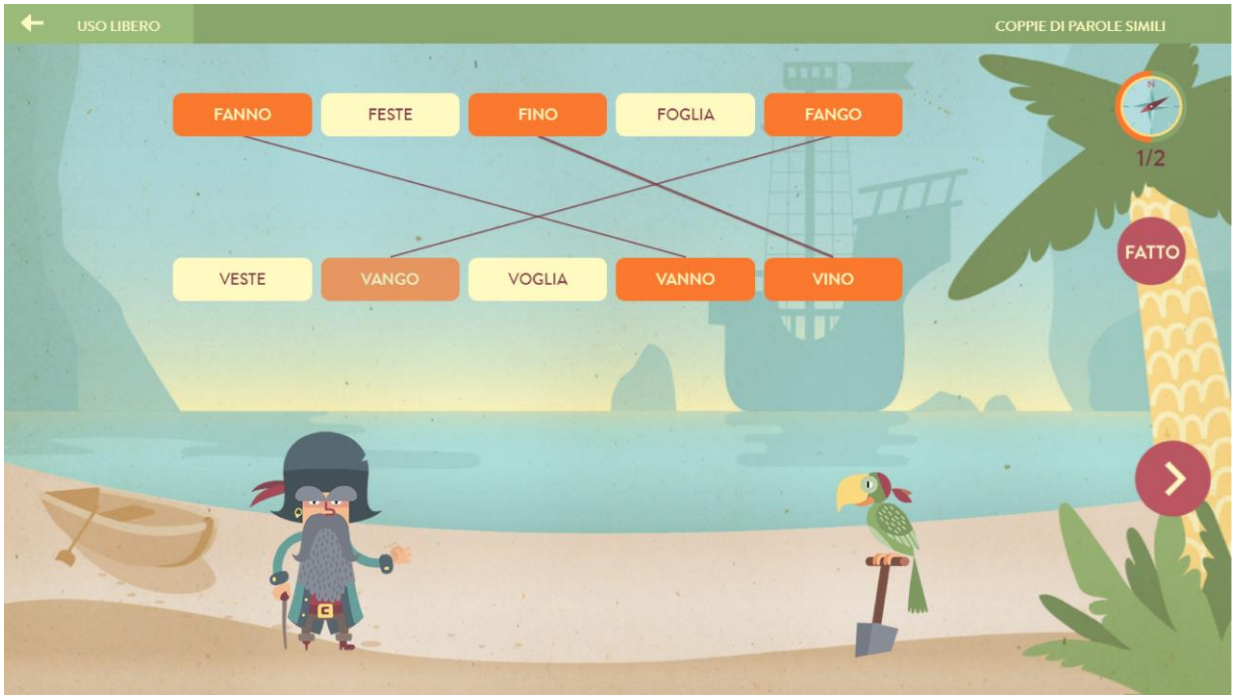

Figure 47. Recupero in Ortografia - "Coppie di parole simili" exercise screen (Ferraboschi and Meini, 2016)

In order to avoid the use of incorrect graphemes, the proposed activities aim to help the child to discriminate and to correctly write the phonemes that correspond to different graphemes, such as GN, GL, SC, CHI/CHE, GHI/GHE, as children often make the mistake of writing the digraphs and trigraphs incorrectly, especially when they are in the orthographic phase of language learning,
Specifically, the exercises are: "Riflessione sul suono GN/SCI e SCE/GLI/CHI" [Reflection on sounds GN/SCI and SCE/GLI/CHI], "Ascolto di parole con GN/SCI e SCE/GLI/CHI" [Listen to words with GN/SCI and SCE/GLI/CHI], "Figure con GN/SCI e SCE/GLI/CHI" [Figures with GN/SCI and SCE/GLI/CHI], Ricerca di GN/SCI e SCE/GLI/CHI tra lettere" [Search for GN/SCI and SCE/GLI/CHI among letters], "Ricerca di parole con GN/SCI e SCE/GLI/CHI" [Search for words with GN/SCI and SCE/GLI/CHI], "Completamento di parole con SI e SCI/SCE e SCIE/GLI o LI/CI o CHI/GI o GHI" [Complete words with SI and SCI/SCE and SCIE/GLI or LI/CI or CHI/GI or GHI], "Completamento di parole in frasi" [Complete words in sentences], "Frasi con errori" [Sentences with errors] (Fig. 48).

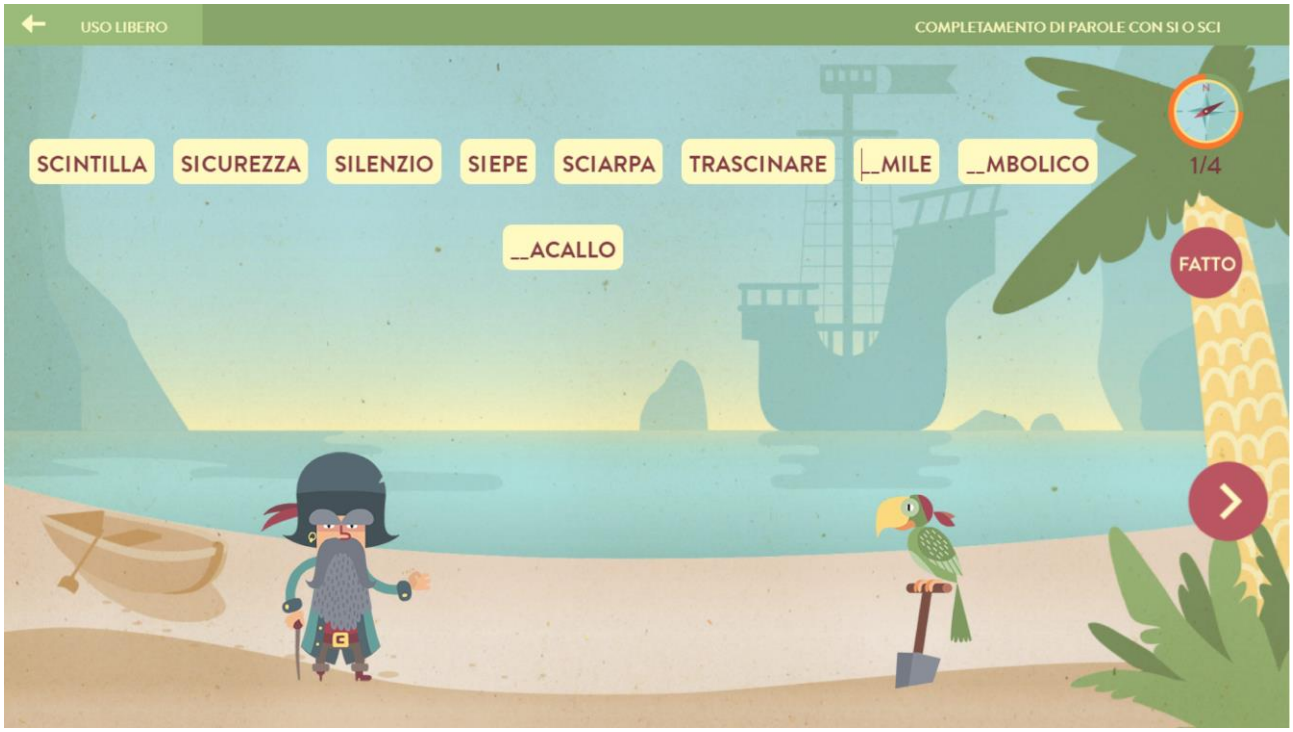

Figure 48. Recupero in Ortografia - "Completamento di parole con SI e SCI" exercise screen (Ferraboschi and Meini, 2016)

Non-phonological errors

These are errors related to the orthographic (visual) representation of words, without errors in the relationship between phoneme and grapheme; therefore, they concern illegal separations (e.g., *in sieme* instead of *insieme*) or illegal merges (e.g., *lacqua* instead of *l'acqua*), exchange of homophonic graphemes (e.g., *squola* instead of *scuola*) and the omission or addition of the letter H (e.g., *lui non a* insted of *lui non ha*).

Children often make the mistake of writing the words all together, making illegitimate merges or separations. It is therefore important to help them perceive the exact number of words within a sentence by using rhythm and counting. The activities train to correctly separate words in writing or to write together the most difficult ones.

Specifically, the exercises are: "Ascolto di frasi e loro numero di parole" [Listen to sentences and counting words number], "Conteggio di parole nelle frasi" [Count words in sentences], "Separazione di parole attaccate in frasi" [Separate words in sentences], "Inserimento di parole in caselle" [Insert words into boxes], "Separazione di parole attaccate in un brano" [Separate words in a text], "Indovinelli" [Riddles] (Fig. 49).

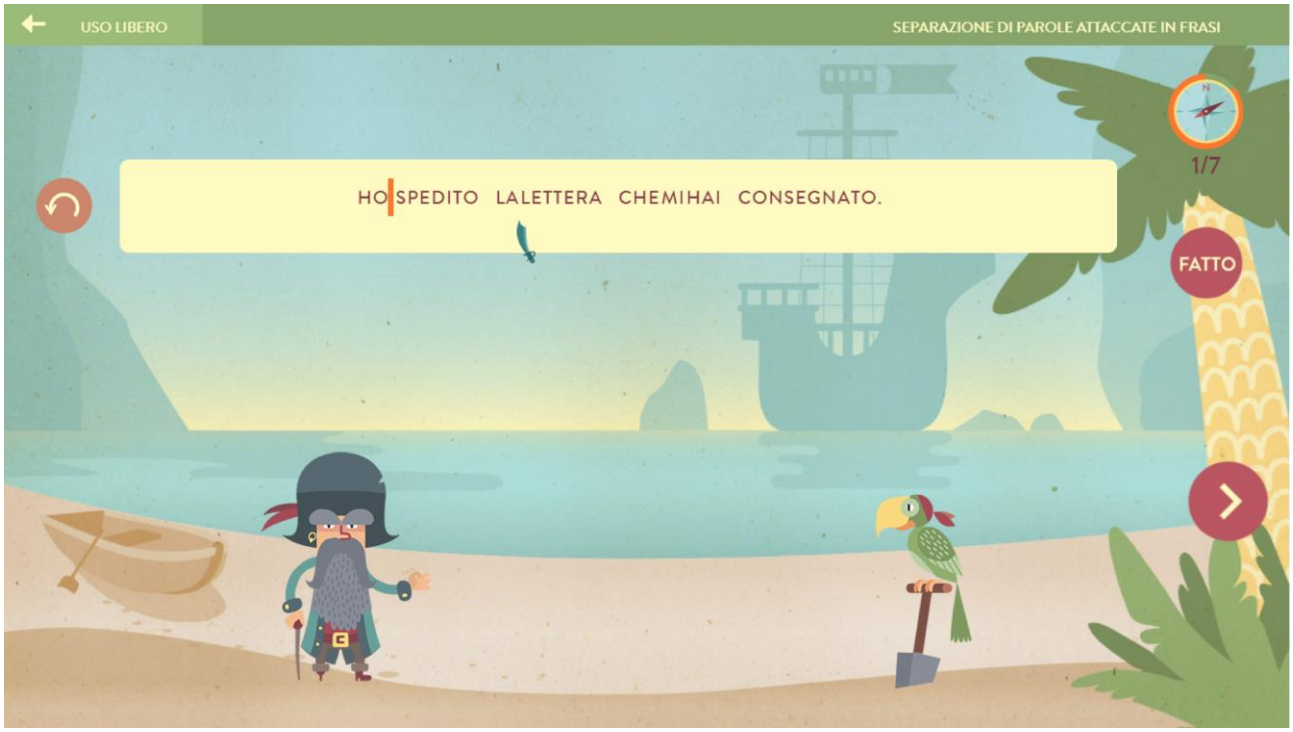

Figure 49. Recupero in Ortografia - "Separazione di parole attaccate in frasi" exercise screen (Ferraboschi and Meini, 2016)

Regarding the use of the apostrophe, the Application aims to make the child discover the incongruity resulting from the meeting of two vowels placed one at the end and the other at the beginning of two words.
Specifically, the exercises are: "L'apostrofo tra articolo e parole" [Apostrophe between article and words], "L'apostrofo in frasi" [Apostrophe in sentences], "L'apostrofo tra preposizione e parola" [Apostrophe between preposition and word], "Riscrivere parole con l'apostrofo" [Rewrite words with apostrophe], "Frasi con errori" [Sentences with errors] (Fig. 50).

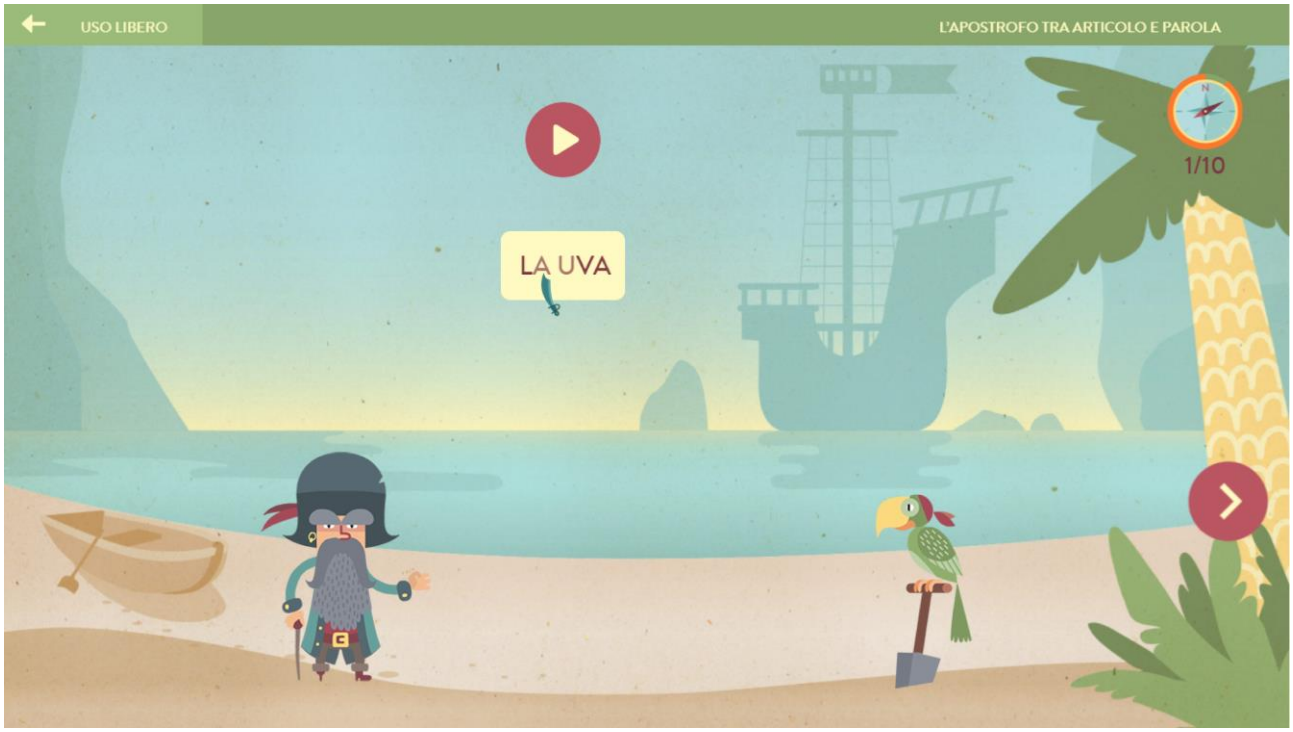

Figure 50. Recupero in Ortografia - "L'apostrofo tra articolo e parole" exercise screen (Ferraboschi and Meini, 2016)

The Application also helps to enhance the use of H, allowing the child to learn the difference between the verb "to have" and the preposition "a".
Specifically, the exercises are: "Riflessione sull'uso dell'H" [Reflection on the use of H], "Scelta di a con o senza H in frasi" [Choice between A or HA in sentences], "Scelta di a con o senza H in brano" [Choice between A or HA in text], "Brano con errori" [Text with errors], "Verbo al passato prossimo" [Verb in perfect past tense], "Verbo al passato prossimo con apostrofo" [Verb in perfect past tense with apostrophe], "Scelta della frase corretta" [Choice of correct sentence], "Frasi con errori" [Sentences with errors] (Fig. 51).

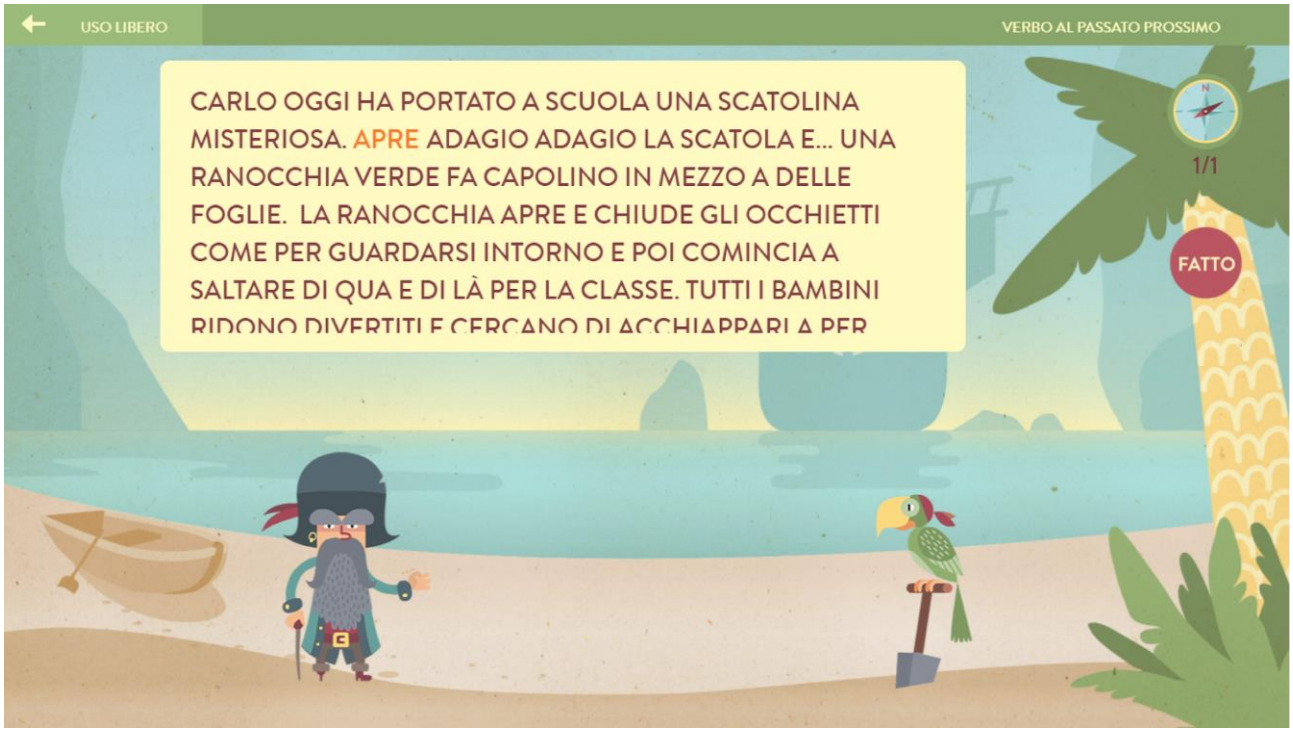

Figure 51. Recupero in Ortografia - "Verbo al passato prossimo" exercise screen (Ferraboschi and Meini, 2016)

The goal of the section related to the exchange of homophone and non-homograph graphemes is to help the child using the lexical way when they must write words that contain homophonic and non-homograph sounds, thus constructing an orthographic (visual) representation of words whose spelling cannot be specified phonologically.
Specifically, the exercises are: "Discriminazione di parole con CU, QU, CQU, CCU" [Discrimination of words with CU, QU, CQU, CCU], "Completamento di parole con CU, QU, CQU, CCU" [Complete words with CU, QU, CQU, CCU], "Completamento di parole in frasi" [Complete words in sentences], "Abbinare ette e parole" [Matching scenes and words], "Affermazioni vere e false" [True and false statements], "Scelta della parola corretta" [Choice of correct word], "Frasi con errori" [Sentences with errors] (Fig. 52).

Figure 52. Recupero in Ortografia - "Completamento di parole in frasi" exercise screen (Ferraboschi and Meini, 2016)

Accents and double letters

These are all the remaining errors and therefore concern the omission or addition of a double letter (e.g., *pala* instead of *palla*) and the omission or addition of accents (e.g., *perche* instead of *perché*).
The activities aim at improving the correct writing of words with double letters and at learning to correctly locate the accent in some words, useful for both reading and writing.
Specifically, the exercises are: "Ascolto di filastrocche" [Listen to nursery rhymes], "Completamento di filastrocche" [Complete nursery rhymes], "Ascolto di parole con le doppie" [Listen to words with double letters], "Ascolto di parole con e senza doppie" [Listen to words with and without double letters], "Parole in rebus" [Words in rebus], "Brano con errori" [Text with errors] (Fig. 53) and "Ascolto di parole con l'accento [Listen to accented words]", "Ricerca di parole con l'accento" [Search for accented words], "Scelta della parola con l'accento corretto" [Choice of word with correct accent], "Accentare parole nelle frasi" [Accent words in sentences], "Accentare parole nelle filastrocche" [Accent words in nursery rhymes] (Fig. 54).

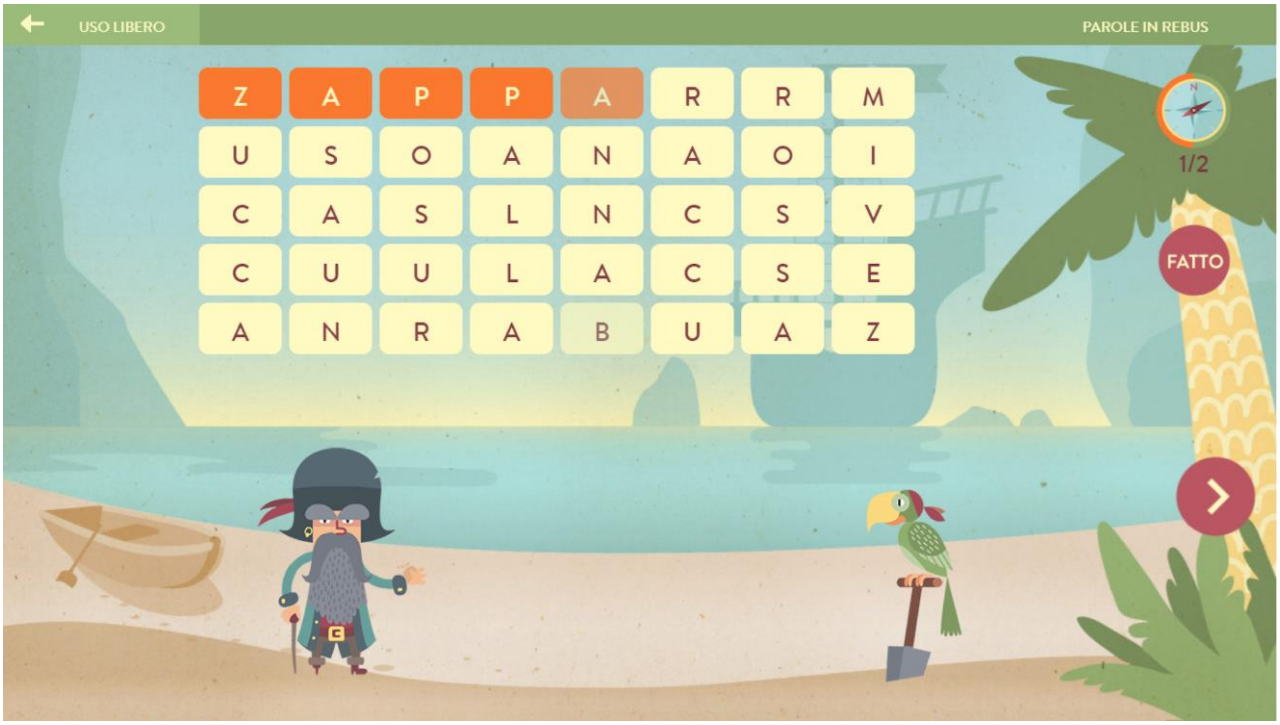

Figure 53. Recupero in Ortografia - "Parole in rebus" exercise screen (Ferraboschi and Meini, 2016)

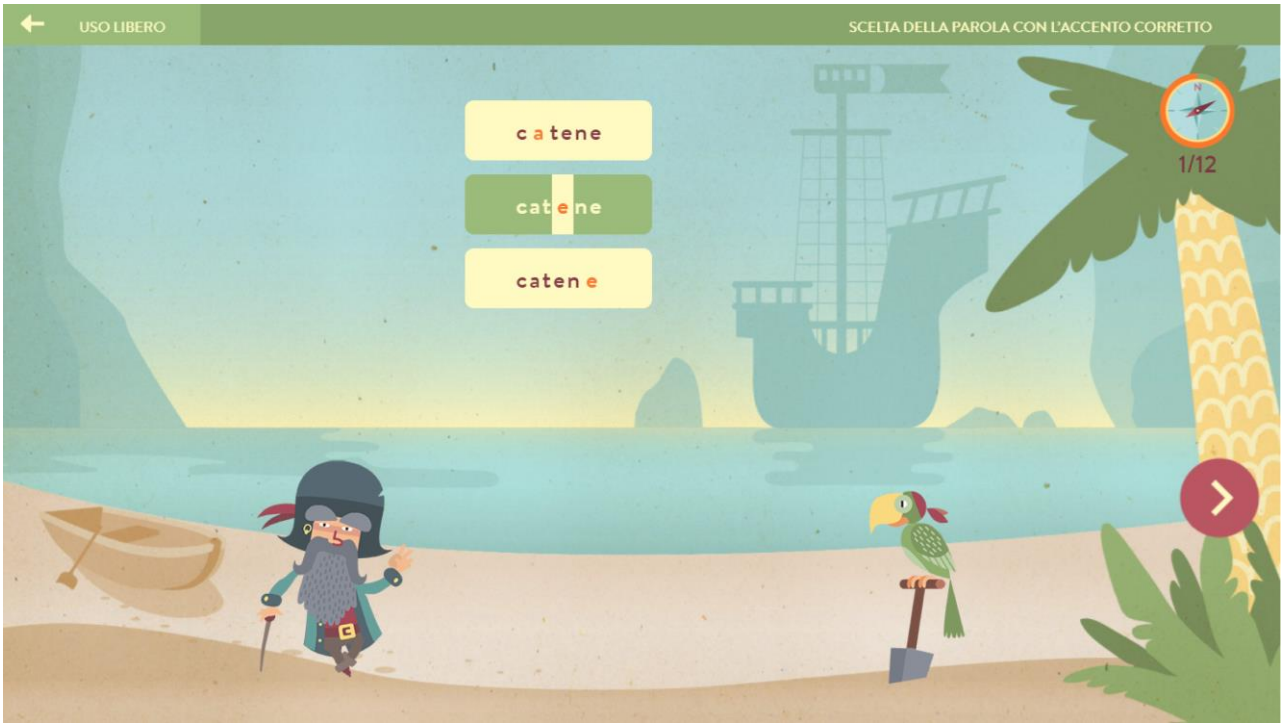

Figure 54. Recupero in Ortografia - "Scelta di parole con l'accento" exercise screen (Ferraboschi and Meini, 2016)

3.4.4.9 *Dislessia e trattamento sublessicale*

[Dyslexia and sublexical treatment] (Cazzaniga et al., 2005)

The book exercises used during the training activities are inspired by Frith's model (Frith, 1986), more precisely the transition phase between alphabetic and lexical phases. Therefore, the activities aim at consolidating reading strategies to allow the automatic identification of syllables. The book proposes a program consisting of six specific work areas, each with a different objective, that are organised in sheets

of increasing difficulty. Each Unit is independent from the others, and, through their different combinations, it is possible to create individualised work plans for each kind of difficulty.

The aim of the first Unit ("*Pa-Ro-La – Oral composition and decomposition of words*") is to introduce the child to the concept of syllables. Through syllable division, the child learns to identify the sublexical unit and is thus facilitated in the transition from letter-by-letter reading to syllabic reading. Therefore, this type of activity is particularly suitable for those children who are still far from spontaneously completing this phase. The sheets include two types of exercises, sorted by increasing difficulty (from bisyllables to pentasyllables), that are syllable division (the practitioner reads the word, and the child performs the division) and syllable fusion (the practitioner reads the syllables, and the child composes the word).

The second Unit ("*Syllable – Quickly read important syllables and words derived from them*") constitutes the heart of the sublexical treatment program, and the child works directly with the written syllable. The exercise, which is repeated through the Unit sheets, consists in the repeated reading of syllables for the automation of syllabic reading process, which requires the memorization of as many syllables as possible. This process occurs gradually and spontaneously in normolectors, while children with Developmental Dyslexia remain anchored to a type of reading that makes use of the grapheme-phoneme conversion procedure. The order of presentation of the syllables (from plain to three-lettered ones) reflects the frequency of use in the Italian language.

Through the third Unit ("*Words composition*") the child learns to recognise the word by manipulating its components (parts of words or syllables). This type of work sensitises the child to the use of the syllabic unit through the composition of words of different lengths starting from the syllables, through the union of a certain number of syllables or, again, the composition of words divided in two. Some sheets contain images that act as facilitators in the process of reconstructing the word.

The fourth Unit ("*Difficult orthographic groups*") aims to improve and automate the immediate recognition of irregular orthographic groups (e.g., gli, gn, ch, etc.). For each consonant group taken into consideration, the sheets follow a program that goes from the acoustic recognition of the sound through the presentation of images; goes through the visual search for words containing the target graphemic group and the reading of sentences; and concludes with exercises, including writing, with words having the target orthographic group and others with a similar consonant group that can lead to confusion (e.g., gi and ghi, ce and che).

The goal of the fifth Unit ("*Fast recognition of words parts*") is to improve the recognition and merging of groups of two or more consonants (e.g., br, str, etc.). Exercises include reading words, phrases, and short stories, as well as searching for words with the target consonant group. The difference with the previous Unit consists in the fact that the trigram, in this case, does not correspond to a single sound, but the correct reading is the result of the association of several phonemes.

The sixth Unit ("Word games") initiates the global reading of the word through quick word identification and self-correction. The exercises, which mainly use the semantic skills of the child, concern the reading and identification of words belonging to a predetermined category, the completion of sentences, with and without the use of images, the correction of sentences containing misplaced words and/or nonwords.

In each Unit, in addition to the worksheets, there are some materials and suggestions for the professional. The book also presents some elements (i.e., the guiding character, Martina the Little Snail; the guiding character's letters addressed directly to the child; the speech bubbles with feedback; the exercises that resemble puzzle games) that could be considered as gamified, as their goal is to motivate children and make them feel protagonist of their learning process (Fig. 55).

Figure 55. Example of exercise, with the guiding character assigning an extra metacognitive activity (Cazzaniga et al., 2005)

3.4.4.10 *Recupero in Ortografia*

[Intervention in orthography] (Ferraboschi and Meini, 2014)

The activities proposed in the book are inspired by the evolutionary model of writing learning by Frith (Frith, 1986) and reflect the three main types of errors (phonological, non-phonological, accents and

double letters). The aim of the book is to raise children's awareness of the error and help them develop strategies to learn how to control automatic writing processes.
The program is divided into three large parts, within which the various types of errors are considered.

1. Phonological errors:
    a. omissions or addition of letters;
    b. inversions;
    c. exchange of graphemes:
        i. discrimination between F/V;
        ii. discrimination between D/T;
        iii. discrimination between P/B;
        iv. discrimination between CE/GE; CI/GI.
    d. digraphs and trigraphs:
        i. GN;
        ii. SCI-SCE;
        iii. GLI;
        iv. CHI-CHE.
2. Non-phonological errors:
    a. illegal separations and fusions;
    b. apostrophe;
    c. use of 'H';
    d. exchange of homophone and non-homograph graphemes.
3. Other errors:
    a. double letters;
    b. accents.

Each program includes methodological suggestions for the teacher and explains how to execute those exercises that involve dictation or listening. Then, there are moments of self-reflection for the students to achieve awareness of the skill to be acquired. Graduated exercises for skills consolidation are divided into specific error exercises and others in which the error to be avoided is normally distributed within the writing task. The child uses assessment sheets to check the acquired skills by comparing the performance with the correct text model. Finally, there are conclusive reflection sheets on consolidated skills and on the procedures activated during the program, with flow diagrams and self-analysis activities, as well as a section of metacognitive reflection in which the student is asked to express, through self-evaluation, their level of satisfaction with learning (Fig. 56).

Figure 56. Example of self-evaluation activity for the student (Ferraboschi and Meini., 2014)

3.4.5 PROCEDURE

At the beginning of the research, in addition to meetings aimed at presenting it to the teachers at the Institutes involved, encounters were organised for the families of children who participated in the study. These encounters aimed at informing parents with respect to the purposes, methods, risks, processing of personal and sensitive data, and the voluntary participation in the project. Subsequently, the information forms, consent to the participation of their children and consent to the collection and processing of data, were submitted.

If there were children in class, who did not take part in the research (i.e., children whose parents did not sign the informed consent form), these stayed within the classroom, with other students, if not otherwise specified. In this way, discrimination and push-out/pull-out phenomena were avoided.
Once all the necessary documents were collected, the following procedures were started.
In the first part of the Study, called T1, participants in both experimental and control groups undertook:

- 45 minutes of collective test, in class, of WISC-IV subtest Reasoning with Matrices (Orsini et al., 2012), and completion of the questionnaire related to school welfare (QBS-B) (Marzocchi and Tobia, 2015). Furthermore, as a psycholinguistic test, the dictation of the text present in the BVSCO-2 battery (Tressoldi et al., 2013) was performed;
- 15 minutes of individual, in a quiet place, linguistic tests, that are lists of words and non-words reading, part of DDE-2 battery (Sartori et al., 2007), and text reading as part of the MT-3 battery (Cornoldi and Carretti, 2016).

Then, for 15 weeks, a collective class treatment took place, with one 50 minutes meeting per week, for a total of about 12 hours.
Gamified Applications Dislessia Evolutiva (Savelli and Pulga, 2016), designed to exercise reading processes, and Recupero in Ortografia (Ferraboschi and Meini, 2016), aimed at improving orthographic correctness, were used for the experimental training. Training programs of increasing difficulty were created. Before the start of the training, each device, identified with an alphanumeric code, was associated with a specific participant per class involved; in this way, each child always used the same tablet with their own profile registered in the Application. During the first training session, the participants mainly became familiar with the device and the Application, they created their own profile, choosing their guiding character or avatar, and indicating their preference for stimuli characteristics (i.e., uppercase/lowercase, written support for auditory verbal explanations). During the training sessions, each child wore earphones to be isolated from the sound feedback of other devices.
Each training session included a first moment in which attendance was taken, followed by the distribution of the tablets and, for Dislessia Evolutiva groups, of a sheet showing the exercises to be done, in the preferred order, including all the parameters to be set (i.e., word length, spelling complexity, stimulus onset time, etc.), different for each class (see APPENDIX B). As for Recupero in Ortografia, on the other hand, the participants could access their personal account where the different exercise maps were saved, with twenty activities each (see APPENDIX C). In this case, the programs were created in such a way that the transition between one activity and the next was only possible when the previous task had been completed.
During exercises, participants received continuous feedback on their performance which acted both as a reinforcement for continuing the target behaviour and as a point of reflection to understand their mistakes and improve. Furthermore, if the subject had continued to make the same error several times for the same exercise screen, the Application automatically presented the next one to avoid increasing the participant's frustration.
As for the control training, the books Dislessia e trattamento sublessicale (Cazzaniga et al., 2005) and Recupero in ortografia (Ferraboschi and Meini, 2014) were used, both offering exercises similar to those proposed in the respective Applications, except for gamification features. Also in this case, a training program was created with exercises of increasing difficulty and as much as possible equivalent to those proposed to the experimental groups. At the beginning of the training phase, each participant was given a book, in which they wrote their name to be able to leave it at school to use it in subsequent sessions.
Each training session included a first moment in which attendance was taken, followed by the distribution of the books. Then, activities scheduled for that specific session were presented (see APPENDIX D and

APPENDIX E). At the end of each exercise, a moment was dedicated to collective correction and children received feedback on their performance.
In both experimental and control groups, the fifteenth training session was divided into two parts. Half of the time, the participants performed the proposed exercises, while the other half they filled out the questionnaire relating to their own experience. Students in the experimental condition, using the tablet connected to the SurveyMonkey platform, filled out the entire questionnaire aimed at investigating the gameful experience and aspects related to motivation and intrinsic need satisfaction; students in the control groups, on the other hand, were asked to fill in only the third part of the questionnaire, relating to intrinsic needs satisfaction, on a paper-sheet.
During the third and last phase of the research, called T2, the psycholinguistic tests, already performed in T1, were used:

- 20 minutes of collective dictation of the text present in the BVSCO-2 battery;
- 15 minutes of individual lists of words and non-words reading, part of DDE-2 battery, and text reading as part of the MT-3 battery.

It should be noted that for the classes of Pergine 2 Comprehensive Institute it was possible to perform T2 tests within the time initially defined for the research, that is one week after the end of the training phase, whereas, for the classes of the North Rovereto Comprehensive Institute, due to the COVID-19 health emergency, the tests were carried out about six months after the end of the activities.
At the end of the intervention, and after the second data collection, teachers were given a detailed report with the aggregate results obtained by the classes in the various neuropsychological tests, with any improvements achieved, and with the general satisfaction with the training activities.
The procedure is represented in Fig. 57.

Figure 57. Procedure of Study A

3.4.6 STATISTICAL ANALYSIS

All participants' performance measures were transformed into z-scores on the basis of age norms, with the exception of fluid intelligence scores.

1) Training effects of performances (H1 and H2 hypotheses)

A set of analyses, focusing on investigating training effects by comparing T1 and T2 linguistic performances (reading speed and accuracy, and writing accuracy), were run. Group differences were examined by means of Analysis of Variance (ANOVAs or MANOVAs, based on the number of considered variables), even when the assumptions of normal distribution of the data, investigated by the Shapiro-Wilk test, were not met, as ANOVA is robust to departures from normality (Blanca et al., 2017). Analyses were performed with TIME as a within-subject factor and GROUP (experimental VS control) as a between-subject factor. Significances were further investigated by means of post-hoc analyses (Tuckey's test) and effect size was assessed by means of Cohen's *d* index.

Furthermore, correlation analyses were performed (either Pearson's correlation coefficient or Spearman's rank correlation coefficient were calculated, based on the verification of normality and linearity assumptions) to investigate the presence of relationships between two variables of interest, in particular between children's initial linguistic performance (T1) and their chronological age, fluid intelligence score, and reported academic well-being, respectively. Also, an Independent Samples t-test was used to determine whether the linguistic performance means at T1 were significantly different between male and females.

2) The link between Intrinsic Needs Satisfaction and performances (H3a and H3b hypotheses)

A multiple regression analysis was performed to investigate the relationship between fun that children experienced during the activities and the improvement index of linguistic performances, or delta score, that is the difference between the last assessment time point, T2, and the baseline, T1.

Moreover, the effect that satisfaction of basic psychological needs, investigated with a 7-point Likert scale questionnaire (McAuley et al., 1989; Richer et al., 1998), had on performance improvements, based on different training, was then assessed through a causal mediation analysis.

Linguistic skills were, for this purpose, considered as:

- Total Reading Speed, that is the average of speed scores (syllables per second) in word, non-word, and text reading tests;
- Total Reading Accuracy, that is the average of accuracy scores (errors) in word, non-word, and text reading tests;
- Total Writing Accuracy, that is the average of accuracy scores (errors) in a text writing test.

The relationship between learning and motivation can be represented through a triangle in which one of the vertices at the base is the explanatory variable (*X*, i.e., the type of training), the other is the outcome variable (*Y*, i.e., the performance improvement index), and the apex is a variable that acts as a mediator (*M*, i.e., psychological needs satisfaction). In Fig. 58, the different relationships are represented where *c* is the coefficient linking *X* and *Y* (total causal effect, *c'* indicates the coefficient for the effect of *X* on *Y* adjusting for *M* (direct effect), and the product *ab* represents the causal mediation effect (CME) that *X* has on *Y* due to the presence of the mediating effect of *M* (indirect effect).

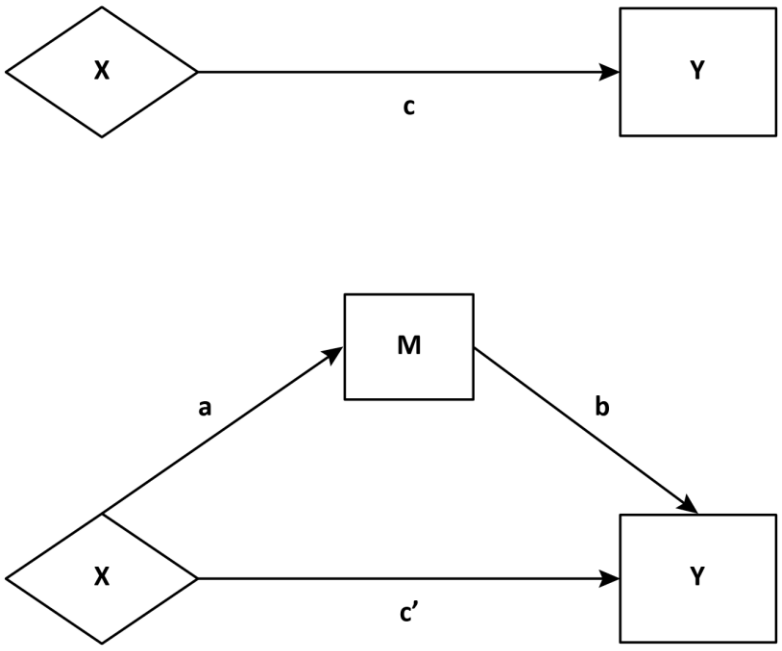

Figure 58. Graphic representation of the causal mediation analysis. X, Y and M are treatment, outcome, and mediator variables. c is the total causal effect, c' is the direct effect, a is the coefficient relating to the effect of X on M, and b is the effect of M on Y adjusting for explanatory variable

3.4.7 RESULTS

3.4.7.1 *Within-subjects analysis*

First, analyses corresponding to the main hypothesis (H1), which concerns the impact of training from pre-test at T1 to post-test at T2, are reported.
In order to assess training effect on linguistic skills, Repeated Measures ANOVAs were conducted, with Time (T1, T2) and Measure (Word, Non-word, Text) as within-subject factors.
Reading speed. A significant Time effect was observed, as children significantly improved their word reading speed of isolated words, either existing or not, and words within a context (see results in Table 9 and Table 10). Post-hoc analyses confirmed that children in both Experimental groups significantly improved their reading time for *words* ($p_{tukey} < .001$), *non-words* ($p_{tukey} < .001$) and *text* ($p_{tukey} < .001$), and in the same way did the children in both Control groups (*words*: C1 $p_{tukey} = 0.001$, C2 $p_{tukey} < .001$; *non-words*: C1 $p_{tukey} = 0.025$, C2 $p_{tukey} < .001$; *text*: C1 $p_{tukey} = 0.034$, C2: $p_{tukey} < .001$).
Results of reading speed are presented in Fig. 59.
Reading accuracy. Analogously, when considering reading accuracy, the Time interaction was significant for all indices. However, post-hoc analyses revealed that only children in the Experimental groups significantly improved in almost every index (*words*: E1 $p_{tukey} < .001$, E2 $p_{tukey} = 0.010$; *non-words*: E1 $p_{tukey} < .001$, E2 $p_{tukey} = 0.629$; *text*: E1 $p_{tukey} < .001$, E2: $p_{tukey} = 0.003$), whereas children in Control groups did not (*words*: C1 $p_{tukey} = 0.340$, C2 $p_{tukey} = 0.995$; *non-words*: C1 $p_{tukey} = 0.840$, C2 $p_{tukey} = 0.597$; *text*: C1 $p_{tukey} = 0.518$, C2: $p_{tukey} = 0.150$).
Results of reading accuracy are presented in Fig. 60.
Writing accuracy. A significant Time effect was observed, for all groups, in writing accuracy. Post-hoc comparisons also revealed significant differences between T1 and T2 for both Experimental ($p_{tukey} < .001$) and Control groups (C1 $p_{tukey} = 0.002$, C2: $p_{tukey} < .001$).
Results of writing accuracy are presented in Fig. 61.
Considering the correlations with linguistic performances at T1, a significant positive interaction between fluid intelligence and almost all indices was found (*reading speed - words*: Pearson's $r = 0.252$***, $p = 0.007$; *non-words*: $r = 0.159$, $p = 0.094$; *text*: $r = 0.271$**, $p = 0.004$; *reading accuracy - words*: $r = 0.383$***, $p < .001$; *non-words*: $r = 0.205$*, $p = 0.030$; *text*: $r = 0.395$***, $p < .001$; *writing accuracy*: $r = 0.249$**, $p = 0.008$); regarding chronological age, instead, only a positive interaction with writing accuracy emerged (Spearman's *rho* = 0.362, $p < .001$). No sex differences resulted from the analysis.

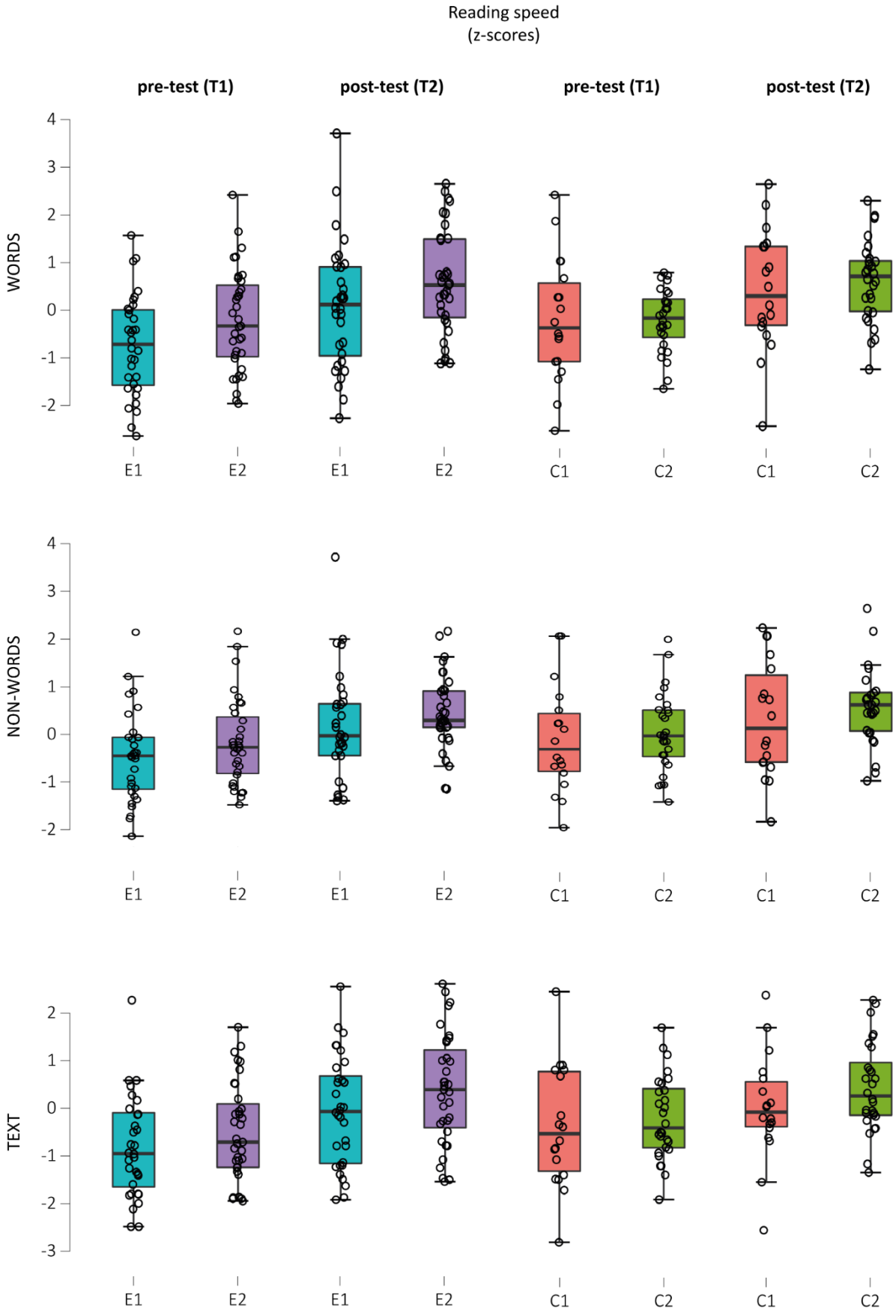

Figure 59. Performances in reading speed, expressed as z-scores, measured before (T1) and after (T2) Experimental (E) and Control (C) trainings

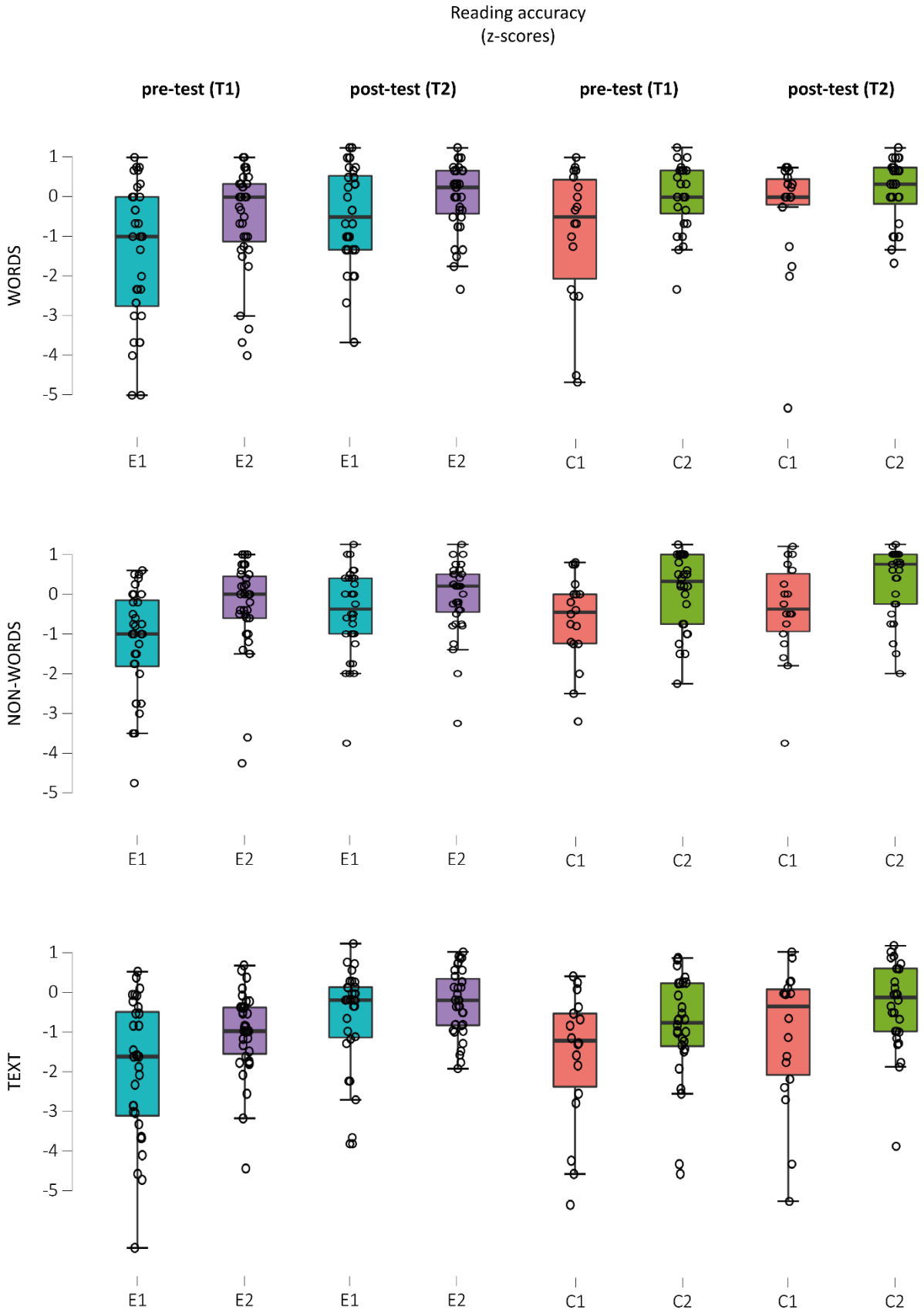

Figure 60. Performances in reading accuracy, expressed as z-scores, measured before (T1) and after (T2) Experimental (E) and Control (C) trainings

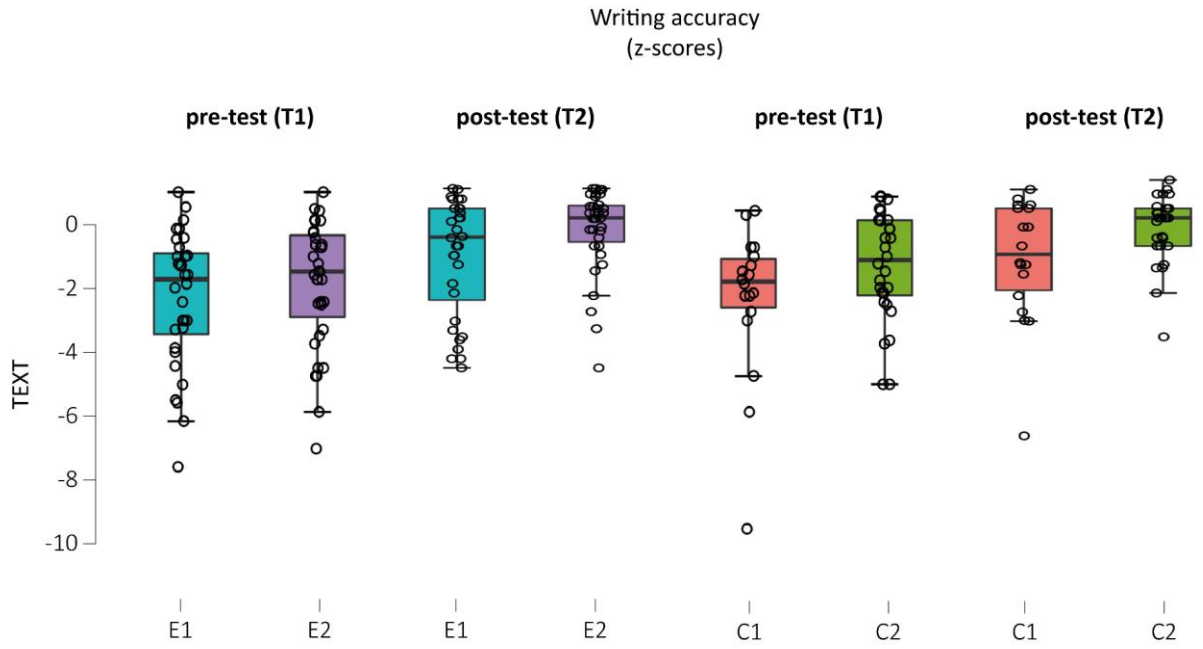

Figure 61. Performances in writing accuracy, expressed as z-scores, measured before (T1) and after (T2) Experimental (E) and Control (C) trainings

Table 9. Intraindividual training effects of Experimental groups on linguistic skills performance [Means (SD)]
[a] Time (T1-T2) x Group interaction
[b] Test significance *p < .05, **p < .01, ***p < .001
[c] Effect sizes of interaction Time : Group expressed as Cohen's *d* (0.01 very small, 0.20 small, 0.50 medium, 0.80 large)

	E1 group (n=32)					**E2 group (n=35)**				
	T1	T2	*F value*[a]	*p*[b]	*ES*[c]	T1	T2	*F value*[a]	*p*[b]	*ES*[c]
Word										
Speed	-0.72 (1.04)	0.08 (1.30)	64.27	<.001	0.68	-0.20 (1.06)	0.59 (1.10)	39.14	<.001	0.73
Accuracy	-1.48 (2.10)	-0.46 (1.23)	18.89	<.001	0.59	-0.56 (1.26)	0.02 (0.87)	15.23	<.001	0.53
Non-word										
Speed	-0.46 (0.94)	0.16 (1.15)	56.64	<.001	0.59	-0.17 (0.91)	0.44 (0.78)	15.23	<.001	0.72
Accuracy	-1.20 (1.40)	-0.45 (1.11)	29.72	<.001	0.59	-0.31 (1.12)	-0.10 (0.91)	15.23	<.001	0.20
Text										
Speed	-0.80 (1.07)	-0.06 (1.15)	98.02	<.001	0.67	-0.51 (1.03)	0.38 (1.16)	106.6	<.001	0.81

Accuracy	-1.94 (2.12)	-0.65 (1.33)	23.58	<.001	0.73	-0.99 (1.17)	-0.26 (0.82)	29.57	<.001	0.72
Writing										
Accuracy	-1.94 (2.12)	-1.00 (1.79)	32.61	<.001	0.48	-1.84 (2.48)	-0.20 (1.28)	44.09	<.001	0.83

Table 10. Intraindividual training effects of Control groups on linguistic skills performance [Means (SD)]
[a] Time (T1-T2) x Group interaction
[b] Test significance *p < .05, **p < .01, ***p < .001
[c] Effect sizes of interaction Time : Group expressed as Cohen's *d* (0.01 very small, 0.20 small, 0.50 medium, 0.80 large)

	C1 group (n=18)					**C2 group (n=28)**				
	T1	T2	*F value*[a]	*p*[b]	*ES*[c]	T1	T2	*F value*[a]	*p*[b]	*ES*[c]
Word										
Speed	-0.19 (1.19)	0.42 (1.27)	38.86	<.001	0.49	-0.20 (0.78)	0.62 (0.85)	56.31	<.001	1.00
Accuracy	-0.93 (1.66)	-0.35 (1.48)	5.36	.033	0.37	0.01 (1.23)	0.12 (0.81)	0.59	.448	0.10
Non-word										
Speed	-0.10 (1.05)	0.32 (1.22)	11.82	.003	0.37	0.03 (0.87)	0.67 (0.98)	47.67	<.001	0.69
Accuracy	-0.63 (1.32)	0.39 (1.22)	1.47	.242	0.80	0.07 (0.98)	0.32 (0.89)	9.08	.005	0.27
Text										
Speed	-0.38 (1.15)	0.02 (1.12)	7.19	.015	0.35	-0.21 (0.95)	0.43 (0.94)	33.08	<.001	0.68
Accuracy	-1.59 (1.94)	-1.08 (1.75)	2.49	.133	0.28	-0.89 (1.50)	-0.32 (1.11)	18.35	<.001	0.43
Writing										
Accuracy	-2.33 (2.98)	-1.10 (1.89)	23.97	<.001	0.49	-1.30 (3.19)	-0.18 (1.04)	24.33	<.001	0.47

3.4.7.2 *Between-subjects analysis*

Analyses corresponding to the second hypothesis (H2), which concerns the impact of training on performance improvements between experimental and control groups, are reported.
In order to assess training effect on improvement index (Δ) of linguistic performances from pre- to post-training, a MANOVA was run, with Group (E1, E2, C1, C2) as between-subject factor.
The results showed there was no significant difference between Experimental and Control groups in linguistic skills improvement, and univariate tests confirmed that there were no significant differences between the paired groups (see Table 11 for detailed results).
Nonetheless, results suggested that the average improvements in reading speed and in reading and writing accuracy were higher for the Experimental condition (*reading speed - words*: M = 0.80, SD = 0.67; *non-words*: M = 0.61, SD = 0.59; *text*: M = 0.82, SD = 0.47; *reading accuracy - words*: M = 0.79, SD = 1.12; *non-words*: M = 0.47, SD = 0.79; *text*: M = 1.00, SD = 1.21; *writing accuracy*: M = 1.48, SD = 1.38) than for the Control condition (*reading speed - words*: M = 0.74, SD = 0.53; *non-words*: M = 0.55, SD = 0.51; *text*: M = 0.55, SD = 0.62; *reading accuracy - words*: M = 0.30, SD = 0.92; *non-words*: M = 0.24, SD = 0.62; *text*: M = 0.54, SD = 1.00; *writing accuracy*: M = 1.16, SD = 1.14).

Table 11. Interindividual training effects of Experimental and Control groups on improvement in linguistic skills performance
[a] Time (Δ) x Group interaction
[b] Test significance *p < .05, **p < .01, ***p < .001

		E1 - C1		**E2 - C2**	
		F value[a]	*p*[b]	*F value*[a]	*p*[b]
Word	Speed	0.83	0.36	0.01	0.90
	Accuracy	0.08	0.78	0.25	0.62
Non-word	Speed	0.20	0.66	1.10	0.30
	Accuracy	0.03	0.87	3.43	0.07
Text	Speed	0.06	0.81	0.04	0.84
	Accuracy	0.96	0.33	0.06	0.81
Writing	Accuracy	0.04	0.85	0.004	0.95

3.4.7.3 *Fun and motivation effects on performances*

Descriptive analyses of the feedback questionnaire demonstrated that the training was well received; the majority of children reported a high approval rating for both gamified (M = 5.98, SD = 1.51) and traditional activities (M = 6.32, SD = 1.15) on a Likert scale from 1 to 7, where 7 corresponds to the

highest degree of fun (see Fig. 62). An Independent Samples t-test revealed no statistically significant differences in the level of appreciation between males and females in both conditions (p = 0.249).

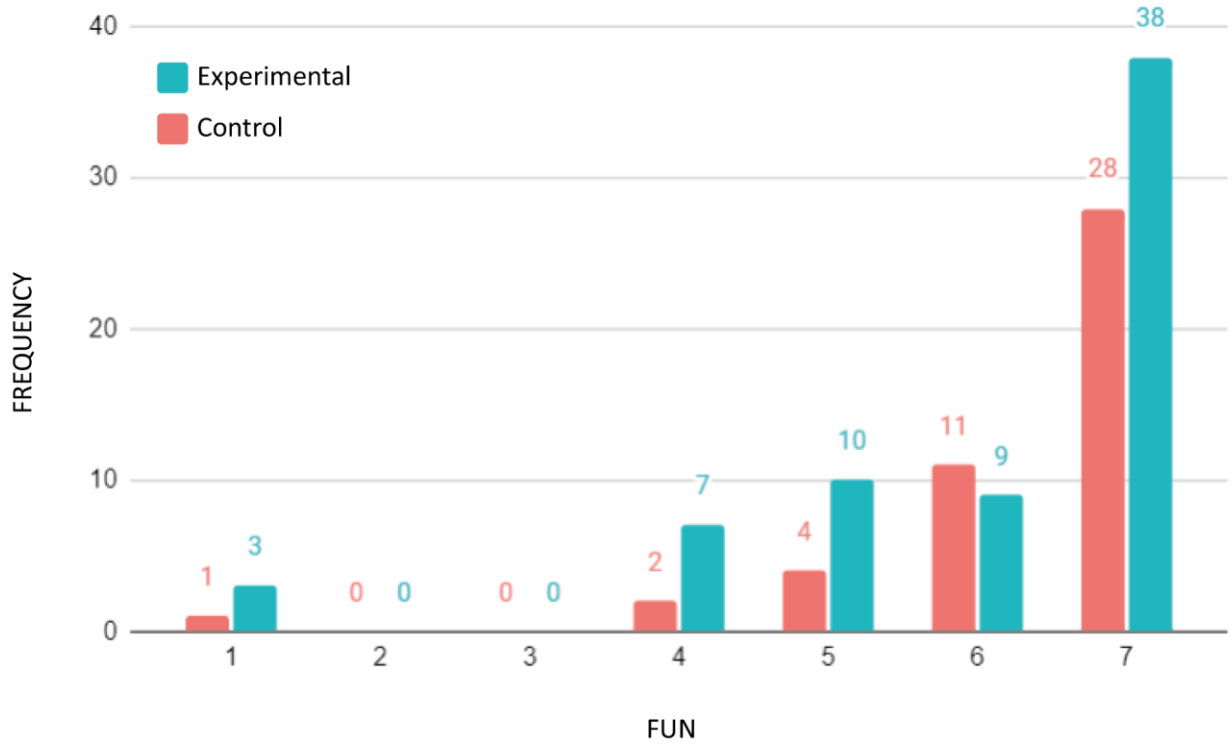

Figure 62. Overall reported fun for both Experimental and Control conditions

To assess whether more fun, experienced by the children during the training activities, resulted in greater performance improvements in linguistic skills (H3a), a multiple regression analysis was conducted, but no significant effect was found.

To assess the significance of the mediating effect of intrinsic psychological needs satisfaction on performance improvements, based on different training (H3b), a causal mediation analysis was then performed.

A three-part questionnaire was used. The *competence* subscale consisted of three (3) items ($\alpha = .72$), the *autonomy* subscale consisted of three (3) items ($\alpha = .56$), and the *relatedness* subscale consisted as well of three (3) items ($\alpha = .83$; Cronbach's α: $0.9 \leq \alpha$ excellent, $0.8 \leq \alpha < 0.9$ good, $0.7 \leq \alpha < 0.8$ acceptable, $0.6 \leq \alpha < 0.7$ questionable, $0.5 \leq \alpha < 0.6$ poor, $\alpha < 0.5$ unacceptable). No significant difference was found, in both experimental and control groups, in psychological needs satisfaction reported by the children.

The results, obtained using a bootstrap confidence interval of 95%, suggested that there was no mediation in the model, that is the improvements in performance were not mediated via psychological needs satisfaction, as reported in Table 12 (see Indirect Effects) and illustrated by the path plot (Fig. 63).

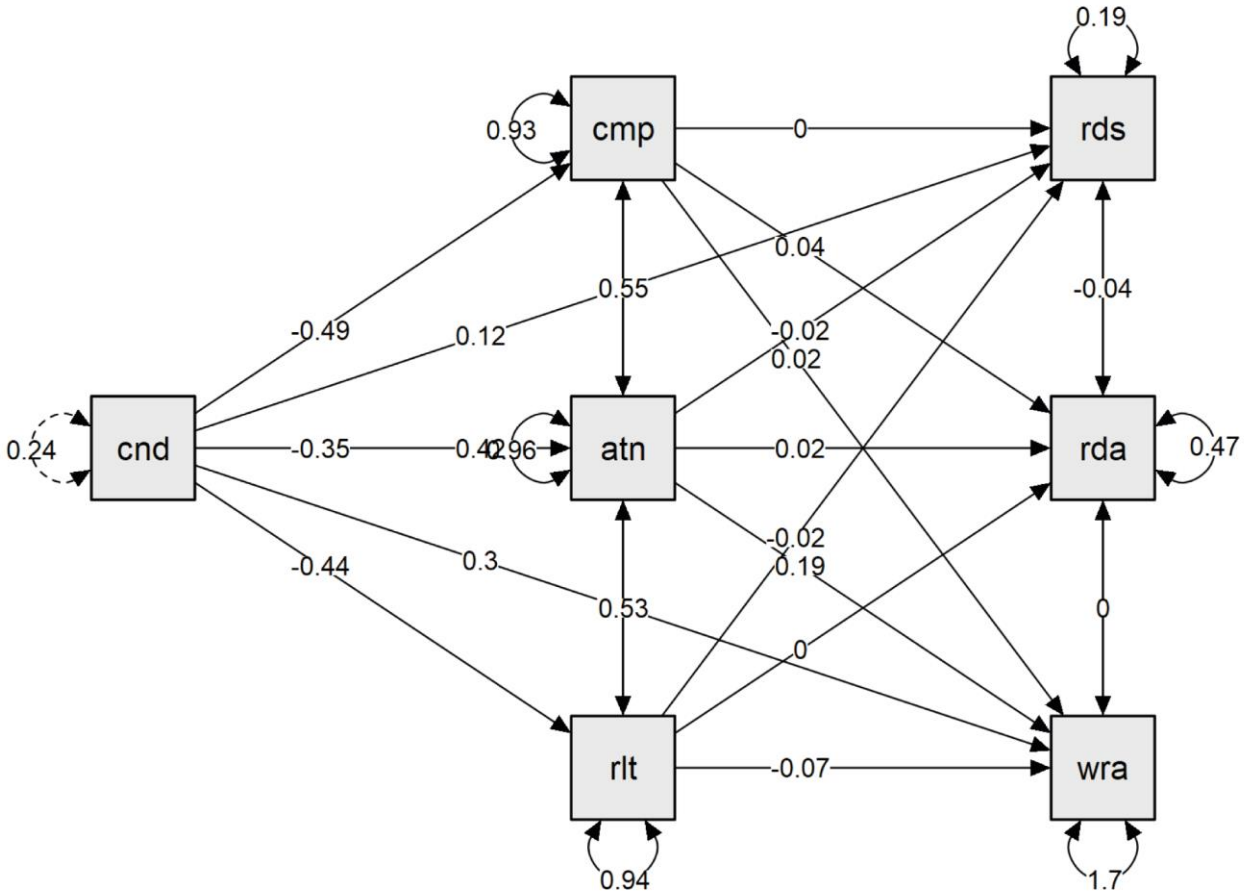

Figure 63. Path plot of causal mediation analysis model. X is the training condition ('cnd'), Y is performance improvements in term of Total Reading Speed ('rds'), Total Reading Accuracy ('rda') and Total Writing Accuracy ('wra'), and M are the mediating variables of Competence ('cmp'), Autonomy ('atn') and Relatedness ('rlt')

Table 12. Direct, Indirect and Total effects of the causal mediation analysis model

Direct effects

							95% Confidence Interval	
			estimate	std. error	*z-value*	*p*	lower	upper
Condition	→	Reading Speed	0.117	0.087	1.345	0.179	-0.052	0.288
Condition	→	Reading Accuracy	0.416	0.137	3.044	0.002	0.155	0.653
Condition	→	Writing Accuracy	0.303	0.258	1.174	0.240	-0.131	0.777

Indirect effects

								95% Confidence Interval	
					estimate	std. error	*z-value*	*p*	lower	upper
Condition	→	Competence	→	Reading Speed	< .001	0.028	-0.036	0.972	-0.075	0.058

Condition	→	Autonomy	→	Reading Speed	0.008	0.020	0.424	0.671	-0.026	0.071
Condition	→	Relatedness	→	Reading Speed	0.007	0.025	0.275	0.783	-0.051	0.075
Condition	→	Competence	→	Reading Accuracy	-0.021	0.044	-0.471	0.638	-0.126	0.062
Condition	→	Autonomy	→	Reading Accuracy	-0.007	0.030	-0.236	0.814	-0.111	0.037
Condition	→	Relatedness	→	Reading Accuracy	< .001	0.038	-0.026	0.979	-0.090	0.072
Condition	→	Competence	→	Writing Accuracy	-0.010	0.082	-0.126	0.899	-0.236	0.207
Condition	→	Autonomy	→	Writing Accuracy	-0.065	0.067	-0.977	0.328	-0.243	0.007
Condition	→	Relatedness	→	Writing Accuracy	0.031	0.073	0.427	0.669	-0.178	0.399

Total effects

							95% Confidence Interval	
			estimate	std. error	*z-value*	*p*	lower	upper
Condition	→	Reading Speed	0.131	0.084	1.555	0.120	-0.028	0.305
Condition	→	Reading Accuracy	0.387	0.132	2.924	0.003	0.127	0.616
Condition	→	Writing Accuracy	0.259	0.252	1.030	0.303	-0.204	0.757

3.4.8 FINAL REMARKS

As expected, given the specific focus of Applications and textbooks used in training linguistic skills, significant improvements in reading speed and in reading and writing accuracy were observed in both experimental and control conditions, following twelve hours of training (H1), whereas no significance was reported in the post-training performances between groups who exercised using gamified Applications and groups who completed the pen-and-paper activities (H2). However, greater improvements were observed for the experimental conditions, as per expectations.

On the other hand, contrary to expectations, neither the fun experienced during the activities (H3a) nor the Intrinsic Needs Satisfaction (H3b) was shown to have a significantly positive nor mediating effect on performance after the training period in any group of subjects.

3.5 Study B

3.5.1 INTRODUCTION

Starting from 2010, the interest for the use of digital educational strategies aimed at children with SEN, both at school and during clinical interventions, has grown (Börjesson et al., 2015) in response to the fact

that such children, showing greater difficulties during learning, show a lower level of motivation (Gooch et al., 2015). The use of gamification with children with SEN was explored more and more; more specifically, studies that involved children with SLD, demonstrated how motivation can increase in relation to the use of gamification (Gooch et al., 2016) and how children report greater fun in the process of learning reading and writing abilities (Cuschieri et al., 2014; Ifigenia et al., 2018), as well as performing better (Dymora and Niemiec, 2019).
Another goal of the present research was, thus, investigating whether the same two gamified Applications — Dislessia Evolutiva (Savelli and Pulga, 2016) and Recupero in Ortografia (Ferraboschi and Meini, 2016) — may enhance literacy skills following a personalised training in children diagnosed with Developmental Dyslexia and / or Dysorthography, as well as increasing their motivation during clinical interventions. Secondly, the post-training performances of the clinical groups were compared with those of children involved in Study A activities (comparisons were differentiated for children with neurotypical development, children with unspecified Neurodevelopmental Disorders and bilingual children).
Specifically, significant intra-group improvements are expected to be observed in children with SLD, as well as higher improvements in literacy skills for the clinical groups compared to Study A groups, due to the personalisation of the training. In addition, it was argued that the enjoyment experienced during the activities along with Intrinsic Needs Satisfaction should lead to a significant improvement in performance following the training.
In the following paragraphs, Study B is presented.

3.5.2 HYPOTHESES

As per research results, the following hypotheses were expected to be verified.
H5. Gamified experience of training is positively associated with better performances in reading and writing tests, as per time factor, comparing pre- and post-training results in children with Developmental Dyslexia and/or Dysorthography.
H6a. Greater performance improvements, between pre- and post-training reading and writing tests, are more strongly predicted by gamified training in children with Specific Learning Disorders compared to children with typical development.
H6b. Greater performance improvements, between pre- and post-training reading and writing tests, are more strongly predicted by personalised gamified training in children with Specific Learning Disorders compared to children with unspecified Neurodevelopmental Disorders or bilingual children who participated in a training proposed in the same way within the class.
H7a. Having fun during the training activities is positively associated with improvements in reading and writing performances, for children with Specific Learning Disorders.
H7b. Intrinsic Needs Satisfaction has a positive impact on performance improvements and acts as a mediator.
H8. Gameful experience positively predicts improvements in reading and writing skills.

3.5.3 PARTICIPANTS

The study included eight to ten years old children with a diagnosis of Developmental Dyslexia and/or Dysorthography. Participants were patients of ODFLab (Laboratorio di Osservazione Diagnosi e Formazione) of the University of Trento Department of Psychology and Cognitive Sciences. The diagnosis was certified by an institution accredited to the national health system according to the ICD-10 inclusion and exclusion criteria, that are: 1a) a delay of at least two standard deviations below the

normative threshold with regard to speed and/or accuracy values in one or more of three reading tests (i.e., word, non-word, text) and or 1b) a performance, in writing standardised tests, below the 5th percentile with regard to correctness parameter; 2) the presence of reading and writing impairment not explained by cognitive, sensory or neurological deficits; 3) the absence of psychopathological disorders and/or other developmental disorders.

Participation was voluntary and required a first informative interview with parents during which they were given the information and consent forms for the child's participation in the research project and for the processing of personal and sensitive data. The interview was also aimed at establishing a relationship of trust between the family and the practitioner. Each participant was free to withdraw from the study at any time and without any consequences.

The subjects who participated in the study are fifteen (15). The sample was divided on the basis of the proposed specific intervention, therefore children diagnosed with Developmental Dyslexia trained speed and accuracy of reading using the Application Dislessia Evolutiva (Savelli and Pulga, 2016) (N = 11), whereas children diagnosed with Dysorthography trained their orthographic correctness using the Application Recupero in Ortografia (Ferraboschi and Meini, 2016) (N = 4). The activities were personalised and individualised according to specific patient's difficulties.

Table 13 shows, in detail, the number of children who participated, specifying the class attended, the Application used and the number of training hours. The total time appears to be different among children, as due to COVID-19, for children with SLD, who need continuous training, in agreement with the psychologists of the ODFLab it was decided to extend the activities period until it was possible to collect post-training data and, consequently, those who had started the project earlier underwent a longer period of training. No significant differences were found between children's T2 performances based on the number of training hours, nor for demographic and cognitive characteristics. The descriptive statistics of the groups are reported in Table 14.

Table 13. Distribution of children by class and experimental condition

Class	Sex	Type of training	1 h meetings	½ h meetings	total h
5	F	APP - Recupero in Ortografia	12	6	15
5	F	APP - Recupero in Ortografia	12	10	17
5	M	APP - Recupero in Ortografia	12	10	17
4	M	APP - Recupero in Ortografia	12	-	12
4	M	APP - Dislessia Evolutiva	13	11	18,5
4	M	APP - Dislessia Evolutiva	13	11	18,5
3	F	APP - Dislessia Evolutiva	12	10	17

4	F	APP - Dislessia Evolutiva	12	-	12
4	M	APP - Dislessia Evolutiva	12	-	12
4	M	APP - Dislessia Evolutiva	12	-	12
3	F	APP - Dislessia Evolutiva	12	-	12
4	F	APP - Dislessia Evolutiva	12	-	12
4	M	APP - Dislessia Evolutiva	12	-	12
4	F	APP - Dislessia Evolutiva	12	-	12
4	F	APP - Dislessia Evolutiva	12	-	12

Table 14. Demographic and cognitive characteristics, and literacy scores (Means, SD) of clinical groups prior to training

[a] Clinical group, APP Recupero in Ortografia

[b] Clinical group, APP Dislessia Evolutiva

[c] $\chi 2$-value, [d] T-value, * sig. $\alpha < 0.05$

	CL1 group[a] (n=4)		**CL2 group[b] (n=11)**			
	M	*SD*	*M*	*SD*	*Test*	*p*
Sex (F-M)	2-2		6-5		0.02[c]	0.88
VCI (WISC-IV)	102.25	12.04	104.20	12.58	-0.17[d]	0.87
PRI (WISC-IV)	106.00	24.10	111.33	12.81	-0.97[d]	0.35
WMI (WISC-IV)	85.75	11.84	88.8	12.70	-0.55[d]	0.59
PSI (WISC-IV)	79.25	15.26	86.13	15.20	-1.06[d]	0.31
LINGUISTIC SKILLS						
Word						
Speed (syll/sec)	-1.77	1.13	-2.15	0.70	0.77[d]	0.45

Accuracy (errors)	-2.46	1..78	-5.72	6.18	1.01[d]	0.32
Non-word						
Speed (syll/sec)	-1.20	1.07	-1.62	0.73	0.87[d]	0.40
Accuracy (errors)	-0.86	1.83	-2.98	2.10	1.78[d]	0.10
Text						
Speed (syll/sec)	-2.16	1.20	-2.40	0.63	0.51[d]	0.62
Accuracy (errors)	-7.44	8.25	-6.60	6.89	-0.20[d]	0.85
Writing						
Accuracy (errors)	-11.20	6.62	-9.63	5.87	-0.45[d]	0.66
Fast Denomination						
Speed	7	4.32	8.45	1.86	-0.94[d]	0.36
Accuracy	2.75	1.26	2.82	1.25	-0.09[d]	0.93
Phonological processing						
Accuracy	7.75	1.71	7.27	1.95	0.43[d]	0.67

During the statistical analysis phase, data collected from the participants belonging to the experimental groups of Study A, were considered both collectively and paying particular attention to the subjects with an unspecified neurodevelopmental disorder and/or bilingual. In particular, two subgroups of six (6) and eight (8) participants were obtained (Table 15). Two separate analyses of the data, obtained from these subgroups, were therefore run and they were then compared with that relating to the group of children participating in Study B.

Table 15. Children who participated in Study A, distributed by subgroup and experimental condition

Subgroup	**Type of training**	**n**
Neurodevelopmental Disorder	APP - Recupero in Ortografia	3
Bilingual	APP - Recupero in Ortografia	3

Neurodevelopmental Disorder	APP - Dislessia Evolutiva	3
Bilingual	APP - Dislessia Evolutiva	5

3.5.4 TOOLS

The tools used for the study were the same used in Study A, except for the fact that the WISC-IV battery was proposed in its entirety (Orsini et al., 2012), being part of the diagnostic procedure, whilst the questionnaire for the assessment of school well-being (QBS 8-13; Marzocchi and Tobia, 2015) was not proposed nor, for reasons related to patient recruitment, was it possible to carry out a control with the use of the two textbooks (Cazzaniga et al., 2005; Ferraboschi and Meini, 2014). In addition, a neuropsychological assessment of cognitive abilities in Language domains was performed through some tests of NEPSY-II battery (Korkman et al., 2007).

3.5.4.1 *WISC-IV: Wechsler Intelligence Scale for Children-IV*
(Orsini et al., 2012)

It is a clinical tool for assessing the cognitive abilities of children aged between 6 years and 0 months and between 16 years and 11 months.
The battery consists of ten main and five additional subtests, which are essential for the calculation of the following four composite scores (as well as the total IQ score):

- Verbal Comprehension Index (VCI) which represents a measure of crystallised intelligence and, in general, of the ability to use verbal concepts and verbal reasoning, and also assesses the amount of knowledge acquired in a formal and informal way and the ability to use it in new situations;
- Perceptual Reasoning Index (PRI) which is a measure of fluid intelligence and, in general, of the abilities of visual-spatial processing, visual-motor integration and coordination and non-verbal reasoning; it also evaluates the ability to interpret and organise visual material to generate useful hypotheses for problem solving;
- Working Memory Index (WMI) which mainly measures short-term memory, more specifically the capacity of working memory, attention and concentration, or the ability to temporarily store information and keep it in memory while performing mental manipulations;
- Processing Speed Index (PSI) which measures the speed in performing simple hyper-learned or automatic tasks and evaluates the subject's ability to scan sequences, quickly and correctly, or distinguish simple visual stimuli; it also assesses short-term visual memory, attention, and visual-motor coordination.

3.5.4.2 *NEPSY-II*
(Korkman et al., 2007)

It is a clinical tool for the neuropsychological assessment of cognitive abilities in three to sixteen years old children, which allows both a global assessment and a targeted investigation of one or more cognitive domains. The battery consists of thirty-three tests that refer to six different cognitive domains, namely: Attention and executive functions; Language; Memory and Learning; Sensorimotor functions; Social perception; Visuo-spatial processing.

For Study B, tests belonging to the Language domains were selected. The tests considered are:

- L3 - Fast Denomination, which investigates the ability to access and identify colours, shapes, sizes, letters and numbers by naming, as quickly as possible and in order, a series of coloured shapes of various sizes, letters and numbers shown in sequence;
- L4 - Phonological Processing, which investigates the ability to recognise segments of words (e.g., me-la, scar-pa) and phonological segmentation of words (e.g., in/dietro, m/oro).

3.5.5 PROCEDURE

Firstly, meetings aimed at presenting the research project to the professionals who collaborated were conducted. Then, the professionals involved organised encounters with the families of children who participated in the study, aimed at informing parents with respect to the purposes, methods, risks, processing of personal and sensitive data, and to the voluntary participation of their children in the project. Subsequently, the information forms, consent to the participation of their children and consent to the collection and processing of data, were collected.

In the first part of the Study (T1), participants undertook 60 minutes of linguistic tests (Sartori et al., 2007; Cornoldi and Carretti, 2016; Tressoldi et al., 2013; Korkman et al., 2007). Furthermore, it was verified whether children had already completed, during the diagnostic process, the WISC-IV battery (Orsini et al., 2012) in order to define their cognitive profile.

Then, an individualised and personalised training, according to children's specific difficulties, took place at ODFLab (Laboratorio di Osservazione, Diagnosi e Formazione) in Rovereto or at Edizioni Centro Studi Erickson in Trento. Meetings of one hour were organised on a weekly basis, for a total of about 12 hours.

In fact, it was demonstrated that 12 hours of play with an action video game are enough to improve attention skills and to increase reading speed in children with Developmental Dyslexia (Franceschini et al., 2013). This connection between attention and reading is demonstrated by the crucial role that visual attention has in learning the identity of the letters and their position. In fact, impairments of visual attention and, in general, of Executive Function (EF) skills are considered an early index to identify children with possible subsequent difficulties in reading and school learning (Benso, 2018).

The total training time appears to be different among children (Table 13) because, due to the COVID-19 emergency, in agreement with ODFLab psychologists, it was decided to extend the activities until it was possible to perform the re-evaluation, with an intensity of 30 minutes per week. This decision was due to the fact that children with SLD need continuous training in reading and writing and, had they not continued such intervention, they would have completed other activities which might have modified the final scores obtained in T2. In addition, also due to the COVID-19 emergency, some meetings were held remotely via Skype, Zoom or Google Meet, with the practitioners sharing the screen of their computer where the Application was shown to the participant.

Participants were divided on the basis of their specific difficulties. Therefore, children diagnosed with Developmental Dyslexia received an intervention for the improvement of reading speed and accuracy using the gamified Application Dislessia Evolutiva (Savelli and Svano Pulga, 2016), whereas children with a diagnosis of Dysorthography or with particular difficulties relating to spelling correctness, experienced a treatment for the enhancement of orthographic correctness using the gamified Application Recupero in Ortografia (Ferraboschi and Meini, 2016).

All the activities, and their difficulty levels, were defined based on the specific profile of the participant with the aim to improve the reading process both in accuracy and speed, by facilitating the fast recognition of syllables or other phonological units that constitute words (sublexical approach), or to

enhance the correctness of writing process. In both cases, the primary goal was to automatise reading and writing skills, also through the creation and extension of the lexicon in increasingly complex activities. Thus, at the beginning of the treatment, single reading units or simple writing tasks were preferred, whereas in the last part of the intervention complete texts, in which words were presented within a context, were used to lead to greater generalisability.

During the last training session, participants remotely filled out the questionnaire, presented on SurveyMonkey platform, that was different based on the Application used during training. The questionnaire aimed at investigating the gameful experience and aspects related to children's motivation and intrinsic need satisfaction.

During the third and last phase of the research (T2), which was completed about two months after the end of training due to COVID-19 emergency, the psycholinguistic tests, already performed in T1, were used.

At the end of the intervention, and after the second data collection, a short online meeting was held with participant's parents, during which they were given a detailed report with the results obtained in the various neuropsychological tests, with any improvements achieved, and the general satisfaction with the gamified training activities reported by the child.

The procedure is represented in Fig. 64.

Figure 64. Procedure of Study B

3.5.6 STATISTICAL ANALYSIS

All participants' performance measures were transformed into z-scores on the basis of age norms, with the exception of cognitive profile scores.

Since the two clinical groups were small in numbers, the subjects of both treatments were considered in a single group for between-subjects analyses, giving priority to assessing the effect that gamification had on reading and writing performances and motivation.

1) Training effects of performances (H5, H6a and H6b hypotheses)

A set of analyses, corresponding to the main hypothesis aimed at investigating training effects on linguistic performances (T1 versus T2), were run. Group differences were analysed by means of Analysis

of Variance (ANOVAs or MANOVAs). Analyses were performed with TIME as a within-subject factor and GROUP (Study B VS Study A subgroups) as a between-subject factor. Significances were further investigated by means of post-hoc analyses (Tuckey's test).
In order to investigate the presence of relationships between two variables of interest, in particular between children's initial linguistic performance (T1) and school grade and cognitive profile respectively, correlation analyses were performed (either Pearson's correlation coefficient or Spearman's rank correlation coefficient). Also, to determine whether the linguistic performance means at T1 were significantly different between male and females, an Independent Samples t-test was run.
From a clinical point of view, the efficacy of the intervention was analysed comparing the improvements in linguistic skills to clinical efficacy criteria. According to the Clinical Recommendations on SLD (P.A.R.C.C., 2011), a treatment is considered effective if it modified the clinical condition more than expected, without professional intervention, in one year of regular education. Several studies revealed that Italian children with Developmental Dyslexia increased by about 0.3 syllables per second their word and text reading fluency, whereas their non-word reading fluency increased by approximately 0.15 syllables per second for each grade (Campanini et al., 2010; Stella et al., 2001; Tressoldi et al., 2001). Considering the clinical significance for accuracy reading, an arbitrary criterion of 50% reduction of errors, with respect to the first evaluation, has been used. As for the writing accuracy, currently there is no reliable longitudinal data to run a comparison.

2) The link between Intrinsic Needs Satisfaction and performances (H7a and H7b hypotheses)

In order to investigate the relationship between fun that children experienced during the activities and the improvement index (Δ) of linguistic performances between pre- and post-training, a multiple regression analysis was performed.
Then, a causal mediation analysis was conducted to assess the effect that satisfaction of basic psychological needs might have had on performance improvements. Linguistic skills were, for this purpose, considered analogously as Total Reading Speed, Total Reading Accuracy, and Total Writing Accuracy.

3.5.7 RESULTS

3.5.7.1 *Within-subjects analysis*

Analyses corresponding to the main hypothesis (H5), which concern the impact of training from pre-test at T1 to post-test at T2, are reported.
In order to assess training effect on linguistic skills, Repeated Measures ANOVAs were conducted, with Time (T1, T2) and Measure (Word, Non-word, Text, Fast denomination, Phonological processing) as within-subject factors.
No main effects were significant; nonetheless, results showed a general improvement (see Fig. 65 and Fig. 66), in presence of intervention, in reading speed, in reading and writing accuracy, and in fast denomination and phonological processing, though not significant.
In the same way, considering the correlations with linguistic performances at T1, no significant interactions emerged with cognitive profile or school grade. No sex differences resulted from the analysis either.
An analysis was performed to assess the efficacy of the training based on clinical criteria (expected improvements without specialist intervention in one year), that are 0.3 syllables per second improvement for word and text reading fluency, 0.15 syllables per second improvement for non-word reading fluency,

and reduction of 50% of the errors for reading accuracy. On an important note, especially for Italian language which has a shallow orthography and thus, in reading disorders, determines a lack of reading fluency, results related to reading speed suggest that 53% of children (N= 8) had an improvement higher than the clinical efficacy criterion, whereas 73% of children (N = 11) improved their reading accuracy more than required by the clinical efficacy criterion.

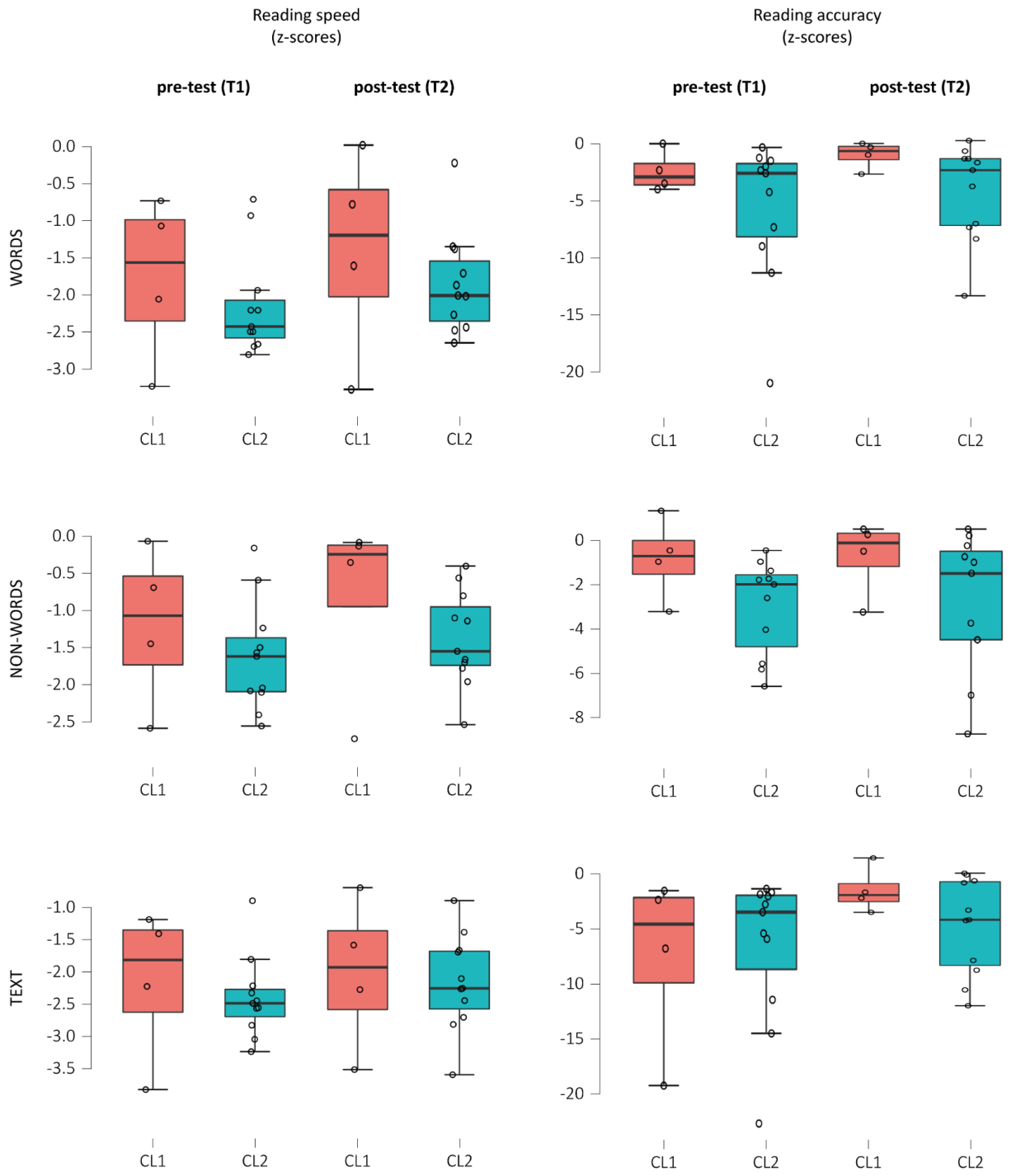

Figure 65. Performances in reading speed and accuracy, expressed as z-scores, measured before (T1) and after (T2) experimental trainings, in children with Developmental Dysorthography (CL1) or Dyslexia (CL2)

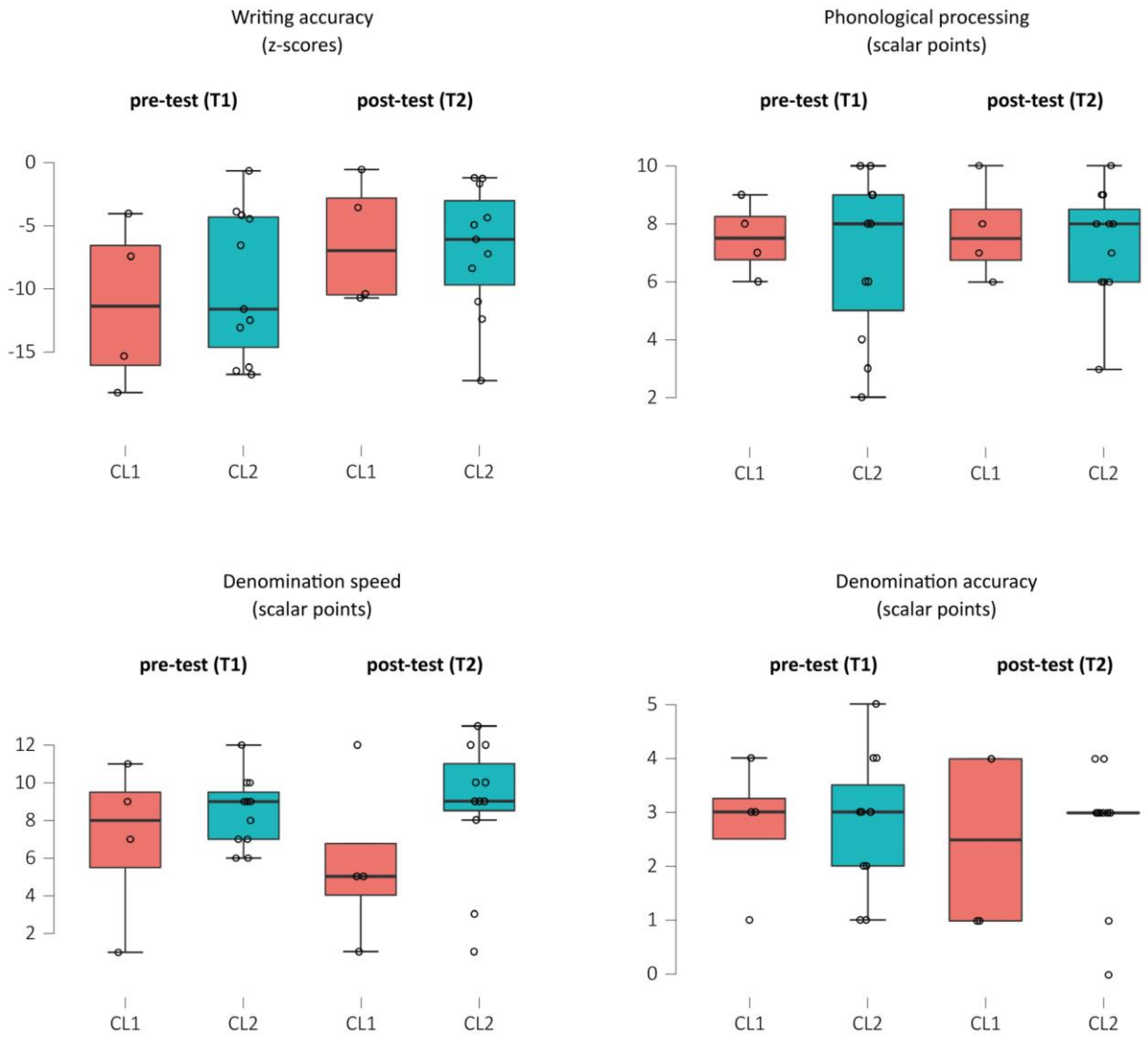

Figure 66. Performances in writing accuracy, expressed as z-scores, and in phonological processing, denomination speed and accuracy, expressed in scalar points, measured before (T1) and after (T2) experimental trainings, in children with Developmental Dysorthography (CL1) or Dyslexia (CL2)

Table 16. Intraindividual training effects of Clinical groups on linguistic skills performance [Means (SD)]
[a] Time (T1-T2) X Group interaction
[b] Test significance *p < .05, **p < .01, ***p < .001

	CL1 group (n=4)				**CL2 group (n=11)**			
	T1	T2	F^a	p^b	T1	T2	F^a	p^b
Word								
Speed	-1.77 (1.13)	-1.40 (1.41)	4.27	.175	-2.15 (0.70)	-1.84 (0.69)	0.85	.381

Accuracy	-2.46 (1.78)	-1.00 (1.19)	1.26	.379	-5.72 (6.18)	-4.25 (4.20)	0.62	.451
Non-word								
Speed	-1.20 (1.07)	-0.82 (1.28)	0.06	.823	-1.62 (0.73)	-1.38 (0.64)	0.01	.794
Accuracy	-0.86 (1.83)	-0.75 (1.72)	0.00	.973	-2.98 (2.10)	-2.84 (3.08)	0.04	.838
Text								
Speed	-2.16 (1.20)	-2.01 (1.19)	0.87	.450	-2.40 (0.63)	-2.16 (0.74)	0.98	.347
Accuracy	-7.44 (8.25)	-1.74 (1.90)	1.46	.350	-6.60 (6.89)	-4.73 (3.99)	< .001	.977
Writing								
Accuracy	-11.20 (6.62)	-6.36 (5.05)	8.57	.100	-9.63 (5.87)	-6.94 (5.08)	1.74	.220
Fast denomination								
Speed	7 (4.32)	5.75 (4.57)	5.19	.150	8.45 (1.86)	8.73 (3.69)	1.66	.230
Accuracy	2.75 (1.26)	2.5 (1.73)	2.42	.260	2.82 (1.25)	2.72 (1.19)	1.36	.273
Phonological processing								
Accuracy	7.75 (1.71)	7.5 (1.29)	0.25	.668	7.27 (1.95)	6.82 (2.82)	1.02	.338

3.5.7.2 *Comparison with Study A participants*

Impact of the personalised gamified intervention on Clinical groups, compared to the uniformed application of gamification at school on Study A Experimental groups, is reported (H6a).

In order to assess training effect on improvement index (Δ) of linguistic performances from pre- to post-training, a MANOVA was run, with Group (CL1, CL2, E1, E2) as between-subject factor.

The results showed there was a significant difference between Study A Experimental groups and Clinical groups in linguistic skills over time [$F(1, 80) = 6.482$, $p < 0.001$]. Specifically, univariate tests indicated there was a significant effect of gamified training on specific psycholinguistic tests: *words reading speed* [$F(1, 80) = 6.914$, $p = 0.010$], *non-words reading speed* [$F(1, 80) = 4.203$, $p = 0.044$], *text reading speed* [$F(1, 80) =$

21.322, p < .001] and *accuracy* [F(1, 80) = 6.652, p = 0.012], and *text writing accuracy* [F(1, 80) = 11.252, p = 0.001].

Post-hoc analyses, though, confirmed that children with a diagnosis of Developmental Dysorthography had a significantly greater improvement in their reading accuracy of contextualised words (p_{tukey} = 0.007) and in their writing accuracy (p_{tukey} = 0.003) compared to neurotypical children. Conversely, children who used Dislessia Evolutiva Application at school had a significantly greater improvement in their reading time of contextualised words (p_{tukey} < .001) when compared to children with a diagnosis of Developmental Dyslexia. No significant differences between the groups were found in other tests (see Table 17 and Fig. 67 for references).

Table 17. Interindividual training effects of Study A Experimental groups and of Clinical groups on linguistic skills performance

[a] Time (Δ) x Group interaction

[b] Test significance *p < .05, **p < .01, ***p < .001

		E1 - CL1		**E2 - CL2**	
		t^a	$p_{tukey}{}^b$	t^a	$p_{tukey}{}^b$
Word	Speed	-1.25	0.60	-2.22	0.13
	Accuracy	0.33	0.99	1.03	0.73
Non-word	Speed	-0.80	0.86	-1.81	0.27
	Accuracy	-0.98	0.76	-0.18	1.00
Text	Speed	-2.44	0.08	-4.10	< .001
	Accuracy	3.34	.007	1.33	0.55
Writing	Accuracy	3.66	.003	1.65	0.36

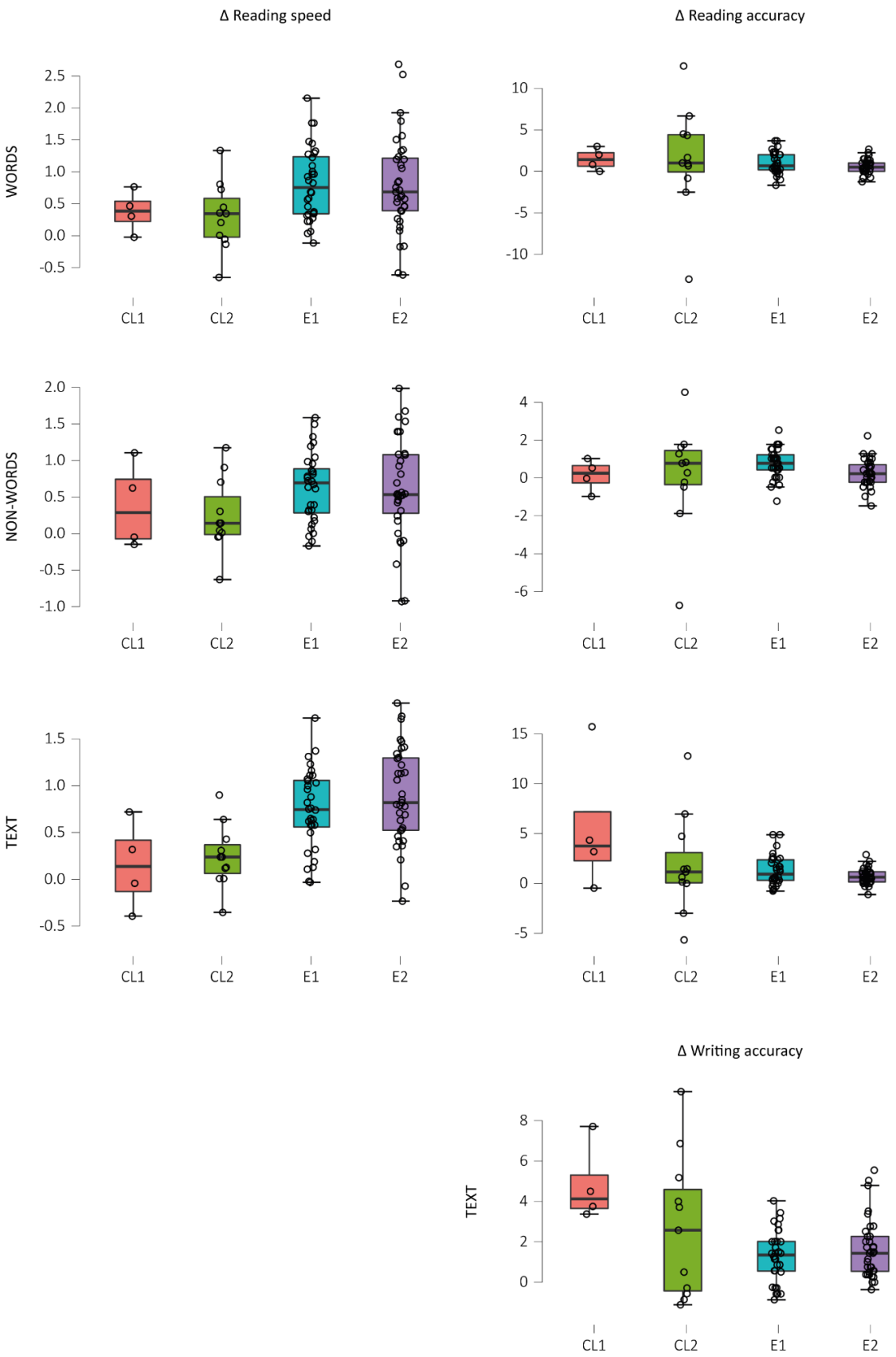

Figure 67. Interindividual comparison of performance improvements (Δ) in reading speed, and reading and writing accuracy, after a gamified period of training at school, in children with neurotypical development (E1 and E2), and after a personalised gamified clinical intervention, in children with Developmental Dysorthography (CL1) or Dyslexia (CL2)

3.5.7.3 *Comparison with Study A participants with Neurodevelopmental Disorders*

First, to assess gamified training effect at school on linguistic skills in children with unspecified Neurodevelopmental Disorders, Repeated Measures ANOVAs were conducted, with Time (T1, T2) and Measure (Word, Non-word, Text) as within-subject factors.

A significant Time effect was observed, as children significantly improved their word reading speed of isolated words, either existing or not, and words within a context. When considering reading accuracy, the Time interaction was significant only for contextualised words. At last, a significant Time effect was observed in writing accuracy (see detailed results in Table 18).

Then, analyses corresponding to the hypothesis (H6b) that concerns the impact of a gamified training, that is the same for every child with unspecified Neurodevelopmental Disorders at school, in comparison with a personalised one for children diagnosed with Developmental Dyslexia and/or Dysorthography, from pre-test at T1 to post-test at T2, are reported.

In order to assess training effect on improvement index (Δ) of linguistic performances from pre- to post-training, a MANOVA was run, with Group (CL, E_ND) as between-subject factor. The results showed there was no significant difference between groups in linguistic skills improvement, and univariate tests confirmed that there were no significant differences between the paired groups (see Table 18 and Fig. 66 for detailed results).

However, results suggested that the average improvements in text reading accuracy and in writing accuracy were higher for children with SLD (*reading accuracy - text*: M = 2.89, SD = 5.56; *writing accuracy*: M = 3.26, SD = 3.27) than for children with unspecified Neurodevelopmental Disorders (*reading accuracy - text*: M = 1.98, SD = 1.60; *writing accuracy*: M = 1.63, SD = 1.44).

Table 18. Training effects of Study A children with unspecified Neurodevelopmental Disorders and children with Developmental Dyslexia and/or Dysorthography on linguistic skills performance [Means (SD)]

[a] Time (T1-T2) X Group interaction

[b] Test significance *p < .05, **p < .01, ***p < .001

	E_ND group (n=6)					**CL group (n=15)**		
	T1	T2	Δ	F^a	p^b	Δ	F^a	p^b
Word								
Speed	-1.68 (1.16)	-1.24 (1.25)	0.43 (0.35)	13.59	.001	0.32 (0.48)	0.28	0.60
Accuracy	-2.54 (1.92)	-0.78 (1.20)	1.76 (1.92)	2.37	0.14	1.46 (5.38)	0.02	0.90
Non-word								
Speed	-1.23	-0.80	0.42	7.92	.011	0.28	0.32	0.58

	(0.95)	(0.98)	(0.59)			(0.51)		
Accuracy	-1.52 (1.46)	-0.52 (1.07)	1.00 (1.53)	0.63	0.44	0.13 (2.39)	0.67	0.42
Text								
Speed	-1.76 (1.11)	-1.15 (1.20)	0.61 (0.68)	9.60	.006	0.22 (0.36)	3.06	0.10
Accuracy	-3.77 (1.87)	-1.79 (1.45)	1.98 (1.60)	6.47	.019	2.89 (5.56)	0.15	0.70
Writing								
Accuracy	-4.83 (2.94)	-3.20 (2.43)	1.63 (1.44)	19.16	< .001	3.26 (3.27)	1.35	0.26

3.5.7.4 *Comparison with Study A bilingual participants*

Analogously to what was done for the Study A subgroup of children with unspecified Neurodevelopmental Disorders, Repeated Measures ANOVAs were conducted, with Time (T1, T2) and Measure (Word, Non-word, Text) as within-subject factors in order to assess gamified training effect at school on linguistic skills in bilingual children.

A significant Time effect was observed, as children significantly improved their word reading speed of words and non-words, and text either. When considering reading accuracy, the Time interaction was significant only for words within a context. At last, a significant Time effect was observed in writing accuracy (see detailed results in Table 19).

Then, analyses corresponding to the hypothesis (H6b) that concerns the impact of a uniformed gamified training for every bilingual child at school, in comparison with a personalised one for children diagnosed with Developmental Dyslexia and/or Dysorthography, from pre-test at T1 to post-test at T2, were conducted.

In order to assess training effect on improvement index (Δ) of linguistic performances from pre- to post-training, a MANOVA was run, with Group (CL, E_BL) as between-subject factor. The results showed there was no significant difference between groups in linguistic skills improvement, and univariate tests confirmed that there were no significant differences between the paired groups (see Table 19 and Fig. 68 for detailed results).

Nonetheless, results suggested that the average improvements in words and text reading accuracy and in writing accuracy were higher for children with SLD (*reading accuracy - words*: M = 1.46, SD = 5.38; *text*: M = 2.89, SD = 5.56; *writing accuracy*: M = 3.26, SD = 3.27) than for bilingual children (*reading accuracy - words*: M = 1.16, SD = 1.44; *text*: M = 1.11, SD = 1.03; *writing accuracy*: M = 2.16, SD = 1.91).

Table 19. Training effects of Study A bilingual children and children with Developmental Dyslexia and/or Dysorthography on linguistic skills performance [Means (SD)]

[a] Time (T1-T2) X Group interaction

[b] Test significance *p < .05, **p < .01, ***p < .001

	E_BL group (n=8)					CL group (n=15)		
	T1	T2	Δ	F^a	p^b	Δ	F^a	p^b
Word								
Speed	-0.99 (1.08)	-0.27 (1.19)	0.71 (0.37)	30.08	< .001	0.32 (0.48)	4.02	0.06
Accuracy	-1.98 (1.84)	-0.82 (1.15)	1.16 (1.44)	5.35	0.06	1.46 (5.38)	0.02	0.88
Non-word								
Speed	-0.26 (0.90)	0.38 (0.87)	0.63 (0.57)	10.00	.016	0.28 (0.51)	2.33	0.14
Accuracy	-1.02 (1.40)	-0.20 (0.99)	0.82 (1.13)	4.30	0.08	0.13 (2.39)	0.59	0.45
Text								
Speed	-1.15 (1.02)	-0.78 (1.15)	0.38 (0.31)	12.40	.010	0.22 (0.36)	1.16	0.29
Accuracy	-2.97 (1.81)	-1.86 (1.38)	1.11 (1.03)	9.31	.019	2.89 (5.56)	0.79	0.38
Writing								
Accuracy	-6.02 (2.74)	-3.86 (2.30)	2.16 (1.91)	19.16	< .001	3.26 (3.27)	0.75	0.40

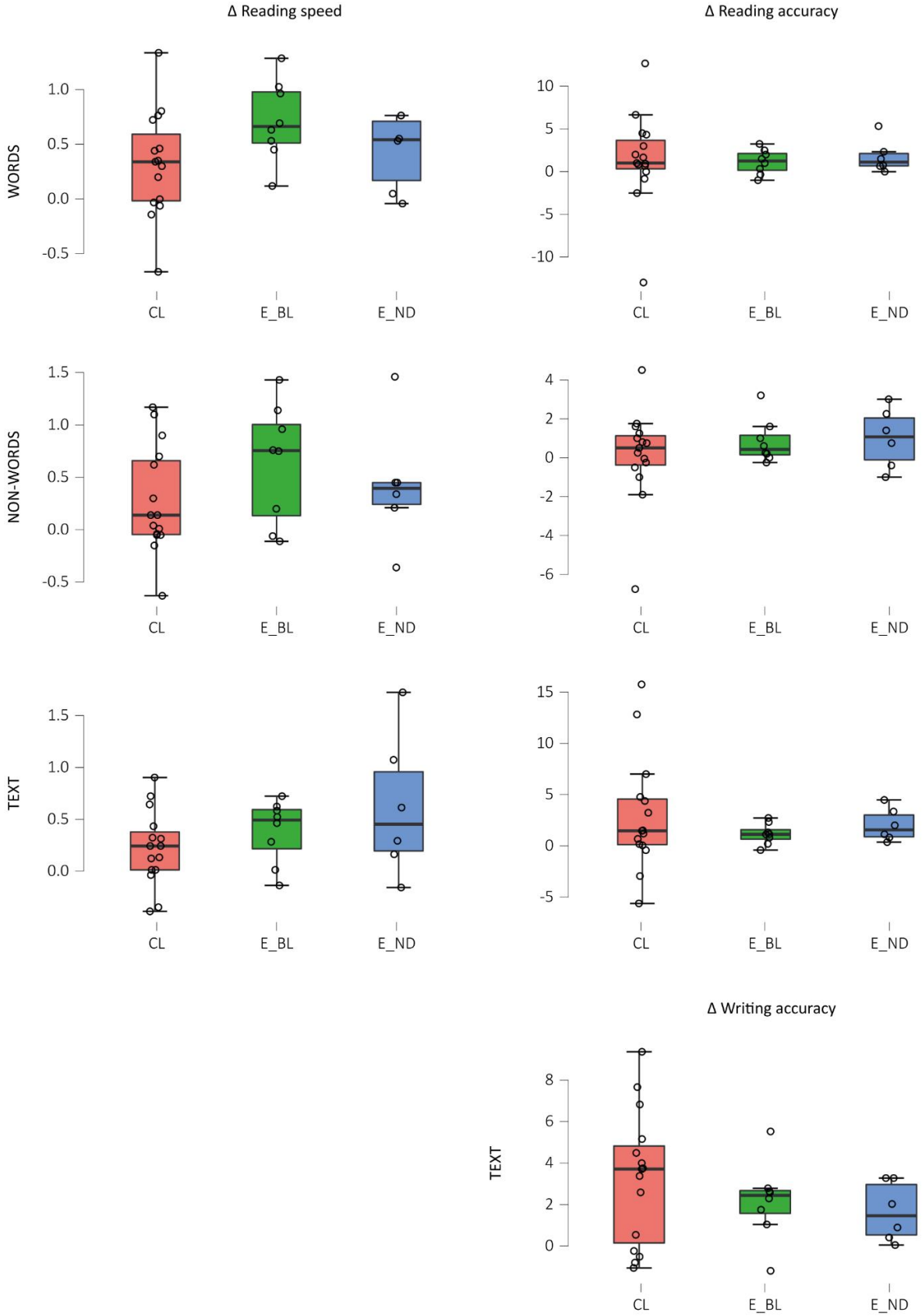

Figure 68. Interindividual comparison of performance improvements (Δ) in reading speed, and reading and writing accuracy, after a gamified period of training at school, in children with bilingualism (E_BL) or unspecified Neurodevelopmental Disorders (E_ND), and after a personalised gamified clinical intervention, in children with Developmental Dyslexia and/or Dysorthography(CL)

3.5.7.5 *Fun and motivation effects of performances*

The training was well received, as demonstrated by the feedback questionnaire descriptive analyses; the majority of children with Developmental Dyslexia and/or Dysorthography (M = 5.60, SD = 1.76), unspecified Neurodevelopmental Disorders (M = 5.67, SD = 2.42) and bilingualism (M = 5.62, SD = 2.20) reported a high approval rating for gamified activities (see Fig. 69). An Independent Samples t-test revealed a statistically significant difference in the level of appreciation between males and females among all conditions (p = 0.014), with females generally enjoying activities the most (females: M = 6.33, SD = 1.59; males: M = 4.86, SD = 2.07).

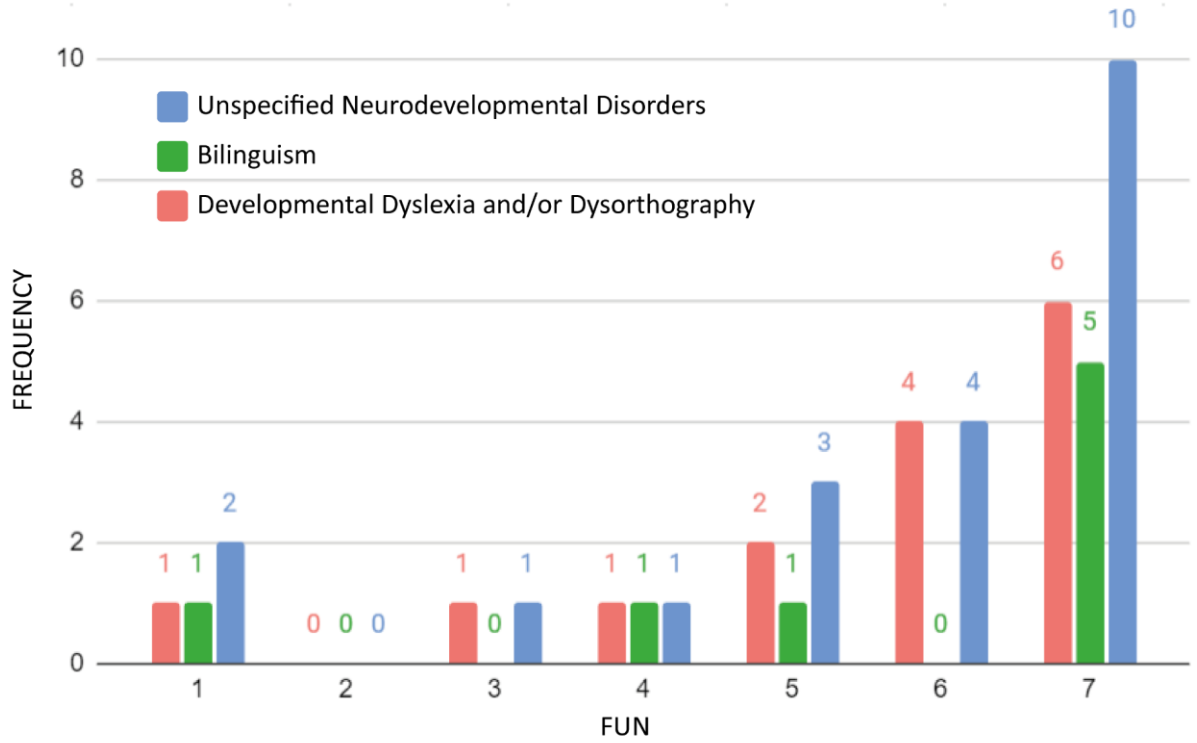

Figure 69. Overall reported fun for children with Developmental Dyslexia and/or Dysorthography, unspecified Neurodevelopmental Disorders and bilingualism

A multiple regression analysis was conducted to assess whether more fun, experienced by the children during the training activities, resulted in greater performance improvements in linguistic skills (H7a). No significant effect was found.

A causal mediation analysis was then performed in order to assess the significance of the possible mediating effect of intrinsic psychological needs satisfaction on performance improvements, based on different training (H7b). The same three-part questionnaire of Study A was used. No significant difference was found, in both clinical and school subgroups.

The results (bootstrap confidence interval of 95%) suggested that there was no mediation in the model, except for an effect, albeit not significant, of *autonomy* on Total Reading Speed (p = 0.085), that is the improvements in terms of syllables per second were mediated via autonomy need satisfaction, as reported in Table 12 and illustrated by the path plot (Fig. 70).

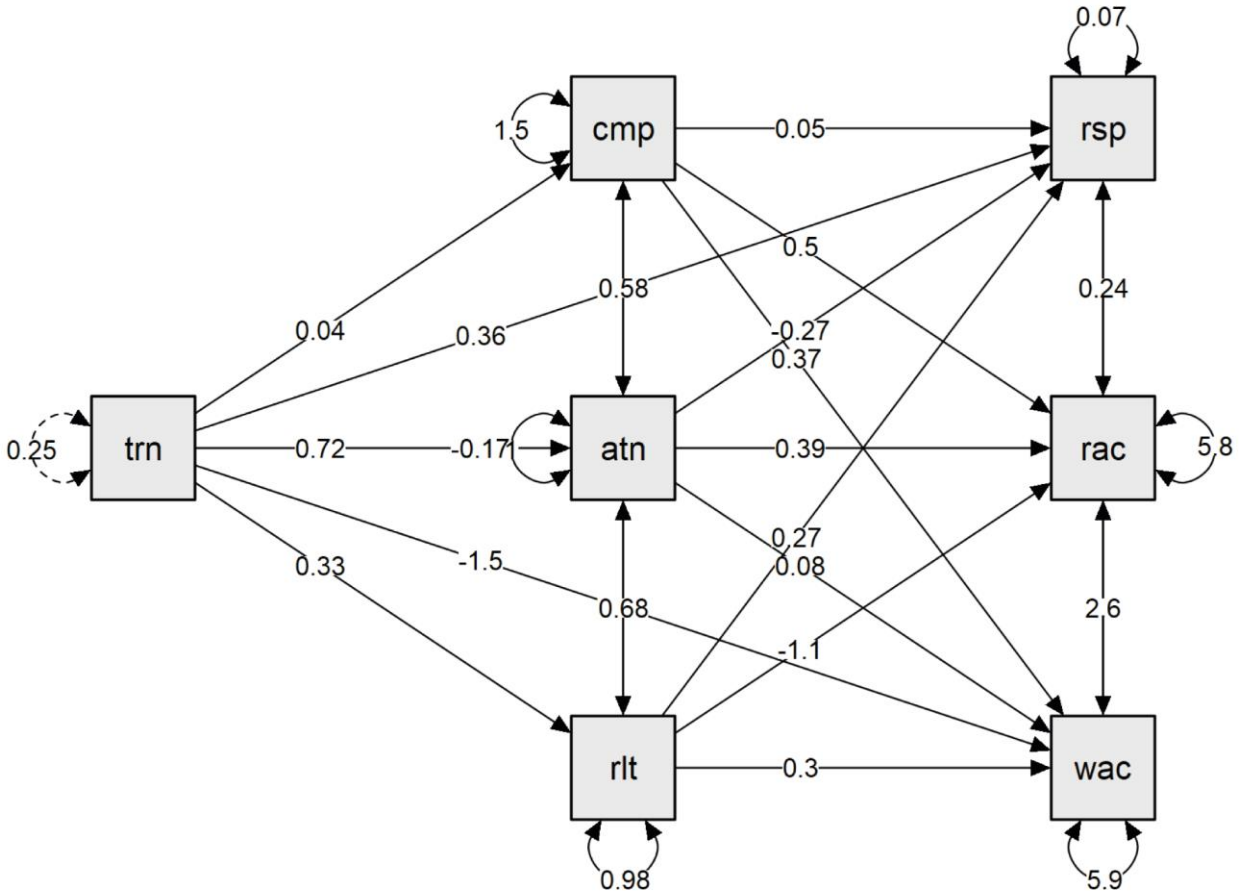

Figure 70. Path plot of causal mediation analysis model. X is the training condition ('trn'), Y is performance improvements in term of Total Reading Speed ('rds'), Total Reading Accuracy ('rda') and Total Writing Accuracy ('wra'), and M are the mediating variables of Competence ('cmp'), Autonomy ('atn') and Relatedness ('rlt')

Table 20. Direct, Indirect and Total effects of the causal mediation analysis model

Direct effects

							95% Confidence Interval	
			estimate	std. error	*z-value*	*p*	lower	upper
Training	→	Reading Speed	0.365	0.110	3.329	< .001	0.114	0.640
Training	→	Reading Accuracy	-0.171	0.967	-0.177	0.860	-1.994	1.768
Training	→	Writing Accuracy	-1.491	0.976	-1.528	0.126	-3.718	0.399

Indirect effects

								95% Confidence Interval	
					estimate	std. error	*z-value*	*p*	lower	upper
Training	→	Competence	→	Reading Speed	0.002	0.025	0.094	0.925	-0.066	0.157

Training	→	Autonomy	→	Reading Speed	-0.192	0.111	-1.724	0.085	-0.507	-0.008
Training	→	Relatedness	→	Reading Speed	0.089	0.104	0.860	0.390	-0.088	0.361
Training	→	Competence	→	Reading Accuracy	0.021	0.227	0.094	0.925	-0.529	1.212
Training	→	Autonomy	→	Reading Accuracy	0.279	0.472	0.591	0.555	-0.418	2.155
Training	→	Relatedness	→	Reading Accuracy	-0.358	0.457	-0.782	0.434	-2.394	0.312
Training	→	Competence	→	Writing Accuracy	0.016	0.168	0.094	0.925	-0.430	1.110
Training	→	Autonomy	→	Writing Accuracy	0.055	0.455	0.121	0.903	-0.777	1.228
Training	→	Relatedness	→	Writing Accuracy	0.098	0.242	0.404	0.687	-0.282	1.781

Total effects

							95% Confidence Interval	
			estimate	std. error	*z-value*	*P*	lower	upper
Training	→	Reading Speed	0.265	0.133	1.996	0.046	0.012	0.536
Training	→	Reading Accuracy	-0.228	0.945	-0.242	0.809	-1.844	1.881
Training	→	Writing Accuracy	-1.322	0.942	-1.404	0.160	-3.083	0.428

3.5.8 FINAL REMARKS

The results (before versus after the personalised training with gamified Applications) showed that, after intervention, children diagnosed with Developmental Dyslexia and/or Dysorthography did not significantly improved in linguistic skills, contrary to what was expected (H5). Crucially, though, most of the children involved had an improvement higher than the clinical efficacy criterion in reading fluency (53% of participants) and in reading accuracy (73% of participants).

Comparisons with Study A participants unexpectedly showed no significant effects, rather they demonstrated mixed results when considering neurotypical participants' post-training performances (H6a); on the other hand, the individualised intervention yielded better results for children with SLD, although not significantly, when compared with post-training performances of children with unspecified Neurodevelopmental Disorders or bilinguals who participated in the school training that was not personalised (H6b).

Also, in the clinical groups and contrary to expectations, neither enjoying the activities (H7a) nor the perceived Intrinsic Needs Satisfaction (H37b) had a significantly positive nor mediating effect on performance after the training period with either Applications.

3.6 Gameful Experience Questionnaire analysis

In order to investigate the link between the improvements in linguistic skills performances and gamification experience for both Study A and Study B children (H4 and H8 hypotheses), three (one for each linguistic skill: Total Reading Speed, Total Reading Accuracy and Total Writing Accuracy) multiple regression analyses were performed.

The questionnaire included two parts, the internal consistency of which was tested using Cronbach's alpha ($0.9 \leq \alpha$ excellent, $0.8 \leq \alpha < 0.9$ good, $0.7 \leq \alpha < 0.8$ acceptable, $0.6 \leq \alpha < 0.7$ questionable, $0.5 \leq \alpha < 0.6$ poor, $\alpha < 0.5$ unacceptable).

The first part involved seven (7) subscales for the assessment of participants' gameful experience: the *Accomplishment* subscale consisted of eight (8) items ($\alpha = .88$), the *Challenge* subscale consisted of eight (8) items ($\alpha = .75$), the *Competition* subscale consisted of seven (7) items ($\alpha = .93$), the *Guided* subscale consisted of seven (7) items ($\alpha = .75$), the *Immersion* subscale consisted of nine (9) items ($\alpha = .89$), the *Playfulness* subscale consisted of nine (9) items ($\alpha = .89$), and the *Social Experience* subscale consisted of eight (8) items ($\alpha = .82$).

The second part, then, involved four (4) subscales for the assessment of frequency and importance of interaction with the different affordances of the gamified Applications used, Recupero in Ortografia (Ferraboschi and Meini, 2016) and Dislessia Evolutiva (Savelli and Pulga, 2016): the *Immersion* subscale consisted of six (6, $\alpha = .54$) and four (4, $\alpha = .74$) items respectively, the *Achievement/Progression* subscale consisted of ten (10) items ($\alpha = .42$ and $\alpha = .74$), the *Social* subscale consisted of two (2) items, and the *Prompts* subscale consisted of two (2) and two (2) items. For Social and Prompts subscales it was not possible to calculate Cronbach's alpha, as the test requires a minimum of three variables.

Interpretations concentrated on the largest principal components of the questionnaire, found through a Principal Component Analysis (PCA). PCA is a dimensionality-reduction method used to reduce the dimensionality of large datasets, by transforming a large set of variables into a smaller one that still contains most of the information in the large set. It divides the independent variables into components, listing them with the level of contribution of the variance. The percentage of total variance, explained by each principal component, was thus calculated and then, all the principal components that explain relatively little variation were ignored in the subsequent analyses.

The output showed that, in the first questionnaire filled in by the children who used Recupero in Ortografia during the gamified training, the first twelve components explain the 76.01 percent of the variance (see Table 21). The scree plot (Fig. 71) indicates that only 12 components, out of 76, are needed to explain the variance, and there is a steep decline from the first two components to the third one on.

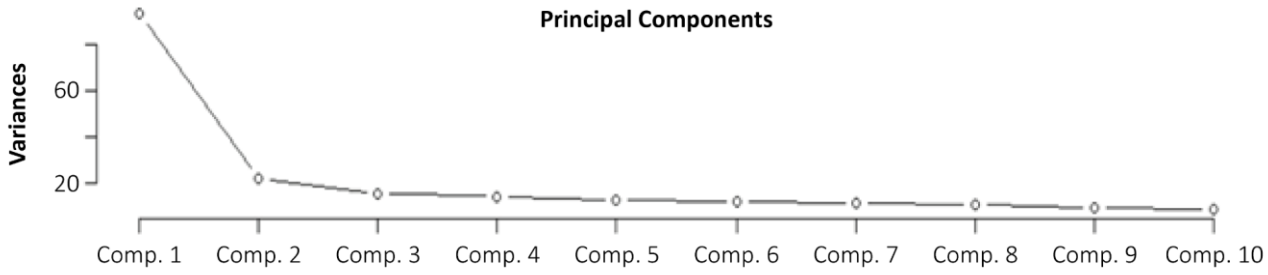

Figure 71. Scree plot of the Principal Components Analysis applied to the 7-points Likert questionnaire related to the gamified training with Recupero in Ortografia

Table 21. Proportions of variance and cumulative proportion for the Principal Components considered

	C. 1	C. 2	C. 3	C. 4	C. 5	C. 6	C. 7	C. 8	C. 9	C. 10	C. 11	C. 12
st. dev.	9.66	4.67	3.92	3.74	3.49	3.40	3.34	3.20	3.03	2.83	2.74	2.59
prop. of var.	.3211	.0748	.0530	.0480	.0419	.0397	.0384	.0351	.0316	.0276	.0258	.0230
cum. prop.	.3211	.3959	.4489	.4970	.5389	.5786	.6170	.6521	.6837	.7113	.7371	**.7601**

Analogously, the same process was applied to the questionnaire filled in by the children who used Dislessia Evolutiva during the gamified training. The output showed that the first eleven components explain the 76.26 percent of the variance (see Table 21). The scree plot (Fig. 72) indicates that only 11 components, out of 74, are needed to explain the variance, and there is a steep decline from the first component to the second one on.

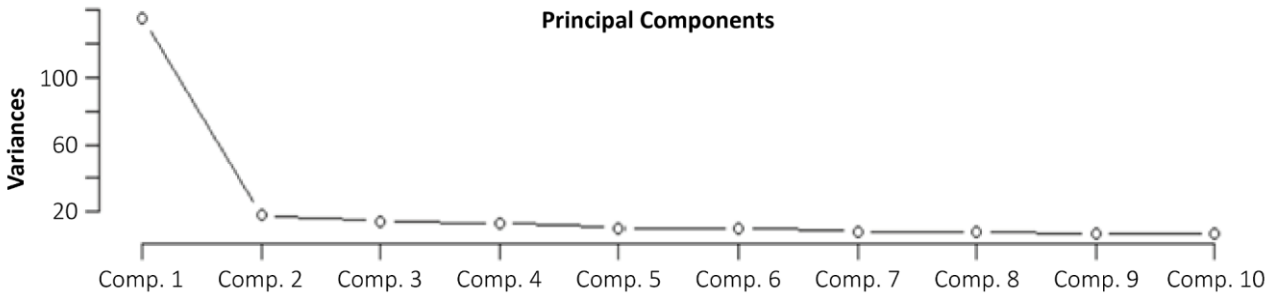

Figure 72. Scree plot of the Principal Components Analysis applied to the 7-points Likert questionnaire related to the gamified training with Dislessia Evolutiva

Table 22. Proportions of variance and cumulative proportion for the Principal Components considered

	C. 1	C. 2	C. 3	C. 4	C. 5	C. 6	C. 7	C. 8	C. 9	C. 10	C. 11
st. dev.	11.61	4.23	3.78	3.63	3.20	3.18	2.89	2.85	2.60	2.56	2.40
prop. of var.	.4376	.0581	.0463	.0429	.0332	.0328	.0271	.0264	.0219	.0212	.0186
cum. prop.	.4376	.4957	.5420	.5849	.6181	.6509	.6780	.7044	.7263	.7476	**.7626**

In Table 23 are reported the questions corresponding to the individuated Principal Components, that are the same for both questionnaires..

Table 23. Items of the questionnaire corresponding to the individuated Principal Components

Construct	Question
	Please indicate how much you agree with the following statements, regarding your feelings while using [Application name]. Overall, [Application name]…
Accomplishment	Makes me feel that I need to complete things

Accomplishment	Pushes me to strive for accomplishments
Accomplishment	Inspires me to maintain my standards of performance
Accomplishment	Makes me feel that success comes through accomplishments
Accomplishment	Makes me strive to take myself to the next level
Accomplishment	Motivates me to progress and get better
Accomplishment	Makes me feel like I have clear goals
Accomplishment	Gives me the feeling that I need to reach goals
Challenge	Makes me push my limits
Challenge	Drives me in a good way to the brink of wanting to give up
Challenge	Pressures me in a positive way by its high demands
Challenge	Challenges me

Then, three multiple regression analyses were performed to explain whether gameful and user experience, during the use of the gamified Applications, predicted improvements (Δ) in linguistic performances, in both Study A and Study B participants. The dependent variables considered were the delta scores of the performances in Total Reading Speed, Total Reading Accuracy and Total Writing Accuracy. Predictors was the gameful experience, expressed by the scores in the first twelve and eleven items of the questionnaire individuated by the PCA.

Regarding the questionnaire related to the use of Recupero in Ortografia Application, none of the regressions was found significant. However, some aspects of the gameful experience accounted for a significant quote of variance for the amount of improvements in Total Reading Speed, specifically *Competition* (63.4%, $R^2 = 0.402$, $p = 0.029$) and *Social Experience* (70.5%, $R^2 = 0.497$, $p = 0.009$), and for the amount of improvements in Total Writing Accuracy, specifically *Immersion* (69.8%, $R^2 = 0.487$, $p = 0.021$).

As for the questionnaire related to the use of Dislessia Evolutiva Application, none of the regressions was found significant. However, some aspects of the gameful experience accounted for a significant quote of variance for the amount of improvements in Total Reading Speed, specifically *Playfulness* (61.8%, $R^2 = 0.382$, $p = 0.026$), in Total Reading Accuracy, specifically *Competition* (60.6%, $R^2 = 0.368$, $p = 0.010$), and in Total Writing Accuracy, specifically *Competition* (56.8%, $R^2 = 0.323$, $p = 0.028$).

Interestingly, affordances related to *Competition* and *Social Experience* were the least present within the two Applications used.

CHAPTER 4 – General discussion and conclusions

Play is an engaging and motivating activity. When individuals play, they experience autonomy, competence, involvement, immersion, and commitment (Barata et al., 2013; Hamari et al., 2014; Lister, 2015), aspects that reinforce intrinsic motivation (Koivisto and Hamari, 2019). As suggested by the Gamified Learning Theory (Landers, 2014), gamification, defined as the use of game elements in non-gaming contexts (Deterding, 2011), can affect behaviour and attitude during learning since, by stimulating motivational mechanisms, it may lead to an improvement in results and objectives (Deterding et al., 2011; Sailer et al., 2014).

Motivation is, indeed, one of the most important aspects to consider during the learning process as it is responsible for starting and continuing an action aimed at achieving a goal. According to the Self-Determination Theory (Deci and Ryan, 1985), intrinsic motivation derives from an internal and autonomous regulation, as individuals consider an action as interesting and motivating in itself, and it increases psychological well-being and guarantees an improvement in performance. Gamification, while encouraging a motivation between introjected and identified regulation dimensions (Ryan and Deci, 2000; Legault, 2017), leads the player to desire to improve through an extrinsic reward system and, indirectly, increases intrinsic motivation. It therefore offers the user an enjoyable, stimulating, and constructive experience, satisfying the three psychological needs of competence, autonomy, and relatedness.

According to Deci and Ryan (Deci and Ryan, 2000), these fundamental psychological needs motivate individuals to learn and act. More specifically, the authors describe the need for autonomy as the desire to feel responsible and to have control over one's behaviour; the need for competence refers to feeling effective in interactions within a context and being able to express one's abilities with the aim of achieving specific objectives; and, at last, the need for relatedness refers to the feeling of being able to relate to and take care of others, being accepted by a community and being part of it. Based on these needs, individuals try to realise their potentials, they are oriented to continually learn and develop their skills (Deci and Ryan, 2002).

There are several studies which showed how the satisfaction of these specific needs can be improved by the use of gamification during the learning process (Kapp, 2012), however there are as many studies in which ambivalent or insignificant effects emerged. In a study by Sailer and colleagues (M. Sailer et al., 2017), for example, it was shown how the design elements of a game can satisfy competence and relatedness, but not autonomy, which requires greater precautions. Furthermore, some gamification affordances act as both extrinsic and intrinsic motivators for certain individuals, depending on the context and the moment (Deterding, 2011). As reported by other authors, gamification does not always have the desired effects, especially when not properly designed (Gee, 2003; Lucisano et al., 2013) and when gamification is used for learning purposes, attention should be paid to the psychological needs of users, their personality and the factors most motivating them (Karanam et al., 2014; Dalmina et al., 2019), since motivational experiences can vary from person to person and have different effects based on the type of user (Huotari and Hamari, 2012; Seaborn and Fels, 2015) and situational and contextual elements (van Roy and Zaman, 2019).

The use of gamification, however, alongside more traditional methodologies and with specific support, can lead to very important improvements as children are more stimulated and involved, especially children with Special Educational Needs, and such didactic strategy could be even more effective if supported and used for the consolidation of information, following an efficient and more traditional teaching process and/or intervention by a specialised adult figure. There are many studies in literature that report how the use of gamification-based applications on tablets had a positive effect in students

with Specific Learning Disorders, as they reported a greater enjoyment in reading and writing learning process while using gamified systems (Ifigenia et al., 2018).
Defining effective interventions is an important challenge for research on Developmental Dyslexia and Dysorthography, as the impairments associated with these learning disorders might negatively influence the possibility to develop a quality life in a society dominated by the written word (Pape et al., 2011). A timely intervention is, thus, fundamental. In this regard, in the last ten years there has been an increasing interest in trying to assess the effects of different methods and tools, such as gamification, also to answer needs of both patients and professionals (Besio et al., 1992; Stella et al., 2011; Aiello et al., 2013; Franceschi and M. Facci, 2013; Pinnelli and C. Sorrentino, 2013; Tucci et al., 2015).
In an effort to overcome scientific inconsistencies and disagreements about gamification, the hereby presented research aimed to analyse its effects and potentials within the educational context to promote an improvement in students' performances and increase their motivation in the learning process, and as an increasingly explored methodology for a new evidence-based intervention based on a multifactorial, probabilistic, model of Specific Learning Disorders.

4.1 Results discussion

In the first study (Study A) the effects of a gamified training at school, with Applications on a tablet, for the enhancing of reading and writing skills, were compared to those of an equivalent, traditional pen-and-paper training in eight- to ten-year-old children. After twelve hours of training, intra-individual improvements in reading and writing performances, both speed and accuracy, were reported. Positive effects of improvement were found for all the groups considered, although it should be emphasised that the participants, in addition to the experimental research training activities, were part of an educational context enriched by stimuli that contributed daily to increasing and enhancing their skills.
In general, considering the school groups, significant improvements in performances are present, and with a good measure of effect, for both indices of reading, speed and accuracy, of words, non-words and text, regardless of the type of training or software used, meaning that the different trainings proved effective in enhancing children's linguistic skills, even though the children in experimental groups, as confirmed by post-hoc analyses, obtained the most positive effects on their reading accuracy improvements.
Results suggested a correct cooperation of the two ways of reading and a greater use, for words and text reading, of the lexical way (Coltheart et al., 2001), which provides for a first recovery of the word and its meaning, to then access its pronunciation; concretely, this translated into an increase in the speed of reading, especially when frequent regular and irregular words were encountered. The exercises focusing on word single units favoured a speed increase in the conversion process, thus positively influencing reading speed. However, there was a less frequent significant improvement in the reading accuracy index in the same tests; this could be due to the increase in the reading speed, which conversely raised up the probability of committing errors and of resorting less to the use of the sublexical reading when new or less frequent words were encountered.
Significant differences were also found between pre- and post-training performances in terms of writing skills. A collaboration emerged between the phonological way, used to write infrequent regular words by exploiting the traditional rules of phoneme-grapheme conversion, and the lexical way, which allows to write irregular words by directly accessing a lexical store which contains words whole abstract form (Savelli and Pulga, 2016); (Tressoldi and Vio, 2012). According to the developmental framework of writing (Frith, 1986), there is a transition for the third graders from the alphabetic stage, in which the

phoneme-grapheme conversion mechanism is mainly used (therefore, as a consequence, the writing process is slowed down and omissions are frequent), to the orthographic stage, in which the speed of reading is no longer influenced by the length of the word or to the complexity of the graphemes, but depends on the nature of the whole word and how frequent it is. As regards the fourth and fifth graders, there is a transition from the orthographic to the lexical stage, in which the orthographic form of the word is recovered from the specific lexicon in which it is stored, and therefore children learn to write the word in its global form. This is an advantage in terms of speed of the writing process and less loss of information during the writing task under dictation.

At an inter-individual level, on the other hand, no significant differences in improvements between pre- and post-training performances emerged for the reading and writing indices of participants belonging to the experimental gamified condition compared to the control pen-and-paper condition. It can, therefore, be assumed that both treatments are effective, as suggested by the intra-individual results, and the two methodologies, being evidence-based and valid strategies (Caponetto et al., 2014), can be used together in order to enhance the learning process.

These results are partially supported by the findings of the second study (Study B) with children diagnosed with Developmental Dyslexia and/or Dysorthography, in which the efficacy of a personalised gamified intervention was evaluated. Assessment upon a twelve-hour training completion revealed that, also for the clinical group, there was an improvement, especially in text reading and writing accuracy, although intra-individual analyses did not result significant. Still, a comparison with clinical efficacy criteria (that are expected improvements without specific and systematic intervention in a year) showed that most of the children with SLD who participated in the Study made equal or larger improvements than in one year of spontaneous reading development, both in reading fluency and correctness. These results are in line with literature (Dymora and Niemiec, 2019; Cuschieri et al., 2014) that demonstrates the efficacy of gamification as a learning support in school-age children with Specific Learning Disorders for the enhancement of speed and accuracy in linguistic tasks.

For the school group with Neurodevelopmental Disorders, a significant difference was found in performances with regard to speed in reading lists of words, non-words, and texts and in the number of errors made in the text reading and writing. It is good to remember, though, the need, for the purpose of effective learning for children with SLD, of personalised and individualised teaching, which was not applied to the school sample.

Another important indication emerged from the group of bilingual children, defined as children who must learn and use two languages, either from birth or in early childhood (Kohnert et al., 2020). According to literature, bilingual children have a slower development rate in each language compared to monolingual peers, especially in vocabulary and grammatical development (Hoff, 2015, Riva et al., 2021). Results showed an improvement in words, non-words, and text reading tests, for speed indices. Instead, there were no significant differences in reading accuracy, except for the text reading test. Such results may be related to bilingual children's greater ability to remember terms and words from different languages, but also their greater difficulty in using the sub-lexical way (Coltheart et al., 2001), probably due to a difference of the Italian writing system, which is alphabetical, and reading system, as it is a transparent language, compared to their mother tongue (Murineddu et al., 2006), hence the improvements in reading correctness only for words within a context. Bilingual children also significantly improved their writing accuracy.

When inter-individual performances were compared, results showed a greater improvement in the clinical group, with respect to the school group, for existing words reading accuracy and writing accuracy after the gamified training with Recupero in Ortografia, but children who used Dislessia Evolutiva Application at school had a significantly greater improvement in their reading time of contextualised words when

compared to children with a diagnosis of Developmental Dyslexia. This is compatible with the greater presence in Italy of cases of phonological dyslexia, as Italian is a transparent language that requires a superior use of the sublexical way of reading (Coltheart et al., 2001). Consequently, the reading time increases but in favour of higher accuracy (Bergmann and Wimmer, 2008). In addition, the average improvements of the clinical group were higher in comparison with Study A children with Special Educational Needs, although not significantly. In fact, children with Developmental Dyslexia and/or Dysorthography improved more in the correctness parameters of reading and writing, when compared to students with unspecified Neurodevelopmental Disorders or bilingual children.

Therefore, an individualised approach and the presence of constant educational support are more effective for the enhancement of reading and writing skills. It thus can be hypothesised that, even for the groups of children with Special Educational Needs, if there had been the possibility of a personalised and individualised training on specific difficulties, it would have been possible to assess even a greater improvement than what emerged.

From the analyses, it can be generally hypothesised that, for children without difficulties, gamified activities have a good effect on reading and writing improvements, even when such activities are proposed in the same way for everyone within the class. Whereas, for children with greater difficulties, there is a need for individualised training to make the most of its benefits. The need for support from a professional and the need to individualise training programs was also found in the study of Sitra and colleagues (Sitra et al., 2017), in which seven- to ten-year-old children with SEN improved in both reading and writing skills thanks to the use of gamification, but within a personalised program. In addition, as reported in another study (Schwaighofer et al., 2015), a competent and emotionally involved professional is needed to better promote the enhancement processes, especially of complex skills such as accurate reading and writing.

Effects were found regarding fluid intelligence, which require a very low linguistic demand (Orsini et al., 2012). As regards the school groups as a whole, therefore bilingual children and children with unspecified Neurodevelopmental Disorders included, this relationship is confirmed for the aspects of both reading and writing, and the statistical significance results for every reading and writing parameter, except for non-words reading speed.

In general, from the analyses, it is possible to hypothesise that there is a positive relationship between fluid intelligence and reading speed, and with reading and writing accuracy. These results are consistent with what is reported in the literature, namely that there is a positive correlation between intellectual abilities and students' learning. Intellectual abilities, especially those related to fluid intelligence, are supported by the same functional network, namely what Kane and Engle (Kane and Engle, 2002) defined the Executive Attention model, with a neural basis in the dorsolateral prefrontal cortex. According to the authors, this model is composed of various components, such as a short-term memory that is in constant connection with the different sensory areas, kept active thanks to the action of the attentional focus which, conversely, has a limited capacity. Furthermore, the authors declared that this network is critical for the prediction of the success of the various functions of high-order cognitive domains, as it is the basis of all cognitive processes, including learning. Consequently, it is possible to infer that higher scores of fluid intelligence correspond to higher results in reading and writing skills.

As for the children in the clinical groups, results mostly showed negative correlations between learning and cognitive indices relating to Verbal Comprehension, Perceptual Reasoning, Working Memory and Processing Speed, although none was significant. Analysing the average weighted scores, it is possible to hypothesise that, as regards the intellectual indices most affected by aspects related to crystallised intelligence, verbal reasoning and influenced by schooling level (i.e., Verbal Comprehension), and in the non-verbal reasoning skills more influenced by fluid intelligence (i.e., Perceptual Reasoning), there are no

impairments in children with SLD, despite having impaired reading and writing skills. However, these children showed greater difficulty in the Working Memory and Processing Speed indices, although the scores are within the normal range (Kane and Engle, 2002).
Such results are in line with several studies which demonstrated that general intelligence does not predict better performances or responsiveness to training in children (Frijters et al., 2011; Fuchs and Young, 2006; Stuebing et al., 2009; Stuebing et al., 2015).
Regarding school welfare reported by the participants, analysing the results, a positive correlation with all the parameters investigated emerged, except in non-words reading speed, but none was statistically significant. On the other hand, in the group of children with unspecified Neurodevelopmental Disorders, there were basically negative correlations, but not statistically significant, in almost all the aspects investigated. This presence of high scores in reported scholastic well-being, but low in learning, may be due to their difficulties in the learning process.
Such results are partially in line with studies in the literature that indicate that learning is better and more effective, the greater the aspects of school well-being perceived by students (Osher et al., 2009; Marzocchi and Tobia, 2015). The school is, indeed, one of the contexts in which children spend a good part of their time, therefore making significant experiences for their emotional, cognitive and relational development and for their sense of self-efficacy and for positive interpersonal relationships, both with classmates and with teachers (Marzocchi and Tobia, 2015).
For all the groups considered, there was no significant effect of Intrinsic Need Satisfaction, investigated as needs of competence, autonomy and relatedness on a 7-point Likert scale (McAuley et al., 1989; Richer et al., 1998; Deci and Ryan, 2000), on improvements in reading and writing performances.
Although at a motivational level no significant mediating effect emerged, it is important to report, especially at a qualitative level, the satisfaction perceived by the children who participated in the various training activities. In fact, in the satisfaction questionnaire investigating how much they liked the proposed activities, participants belonging to the various groups considered, mostly reported the highest degree of satisfaction, an aspect of fundamental importance for the success of the learning process (Ifigenia et al., 2018), and a higher appreciation in the use of gamified software for the enhancement of reading and writing skills compared to traditional pen-and-paper activities. From the data reported, children attributed the lowest scores, both for the school and clinical samples, who presented the greatest difficulties in reading and writing.
At last, in both studies it was investigated the relationship between participants' gameful experience and interactions with several gamification affordances, and their linguistic performance improvements after the period of gamified training. According to the empirical results, none of the gamification features, nor the elicited gameful experience, had a significant predicting relationship with learning outcomes. An interesting aspect of the results, though, was that aspects related to competitive and social dimensions, which characterised the Applications at least, were positively associated with total improvements in linguistic fluency and correctness. Another important role was played by immersion and playfulness related features, whereas accomplishment, challenge and guiding aspects were the least predictive. It remains an elusive point as to why such aspects showed a more modest effect on learning; however, this may have been due to the fact that the gamified Applications used differ significantly from other game environments in which immersion and narrative experiences are more perceived, and goals and achievements are more evident. The interesting effect of competition and social experience dimensions, on the other hand, may have been due to the fact that children performed the activities along with peers, within the school context, and in the presence of the practitioner, during the clinical intervention, when, usually, the use of gamified Applications is solitary, and competitive and social aspects are delegated solely to the features actually present in the software.

The empirical research on the effectiveness of gamification is not very extensive, especially on groups of subjects attending Primary School; however, the results are mixed: some studies report an improvement in students who improve their performances and are positively involved (Lee and Hammer, 2011); (Marcos et al., 2014); others, on the other hand, report insignificant results in terms of performance compared to traditional exercises. The findings of the hereby presented research are not directly in adherence with hypotheses and seem to align with other studies (Domínguez et al., 2013; Hanus and Fox, 2015; Katz et al., 2014; Toda et al., 2018) in which no statistically significant difference in efficacy emerged when comparing the effects of a gamified training to those of a traditional one.
Nonetheless, intra-individual differences emerged, and gamified training proved satisfactory in enhancing reading and writing performances. Moreover, qualitatively observing both the experimental and control training sessions at school, a general enthusiasm for the proposed activities emerged as they offered a different and innovative teaching method, which positively influenced participants' attitude towards the proposed activities, regardless of the effect on performances in the psycholinguistic tests.
Such enthusiasm and proactivity remained almost unchanged in the experimental groups. Participants were visibly happy to use the Applications on the tablet, they were concentrated, appeared committed, and motivated, especially during more complex activities. Even less motivated students, who showed less appreciation for training on reading and writing skills, with gamified software, were positively involved and were able to stay focused for a good part of each training session. Gamified activities also seemed to have positive effects on class well-being, as students interacted and compared constructively with each other, without anyone appearing better than another, as proved by the results from GAMEFULQUEST analyses, specifically from *Competition* and *Social Experience* aspects. An atmosphere of constructive competition emerged, and it often happened that some participants, more skilled in the use of the technological device or in the understanding of an exercise, helped their peers in difficulty. Gamification, as also reported in another study (Bowker, 2017), made the educational context much more appealing, favouring personal initiative and solidarity among peers.
In the subjects assigned to the control conditions at school, on the other hand, the interest in the proposed activities gradually decreased over time. Often, the students were visibly divided in a group positively motivated to perform the proposed activities, profitably interacting with the experimenter and peers, and another group, often composed by students with some difficulties or not motivated, that was slow and performed fewer exercises than assigned.

4.2 Conclusions

Gamification refers to the use of game elements, to improve involvement and perseverance, in traditionally non-gaming contexts, such as education or rehabilitation (Deterding et al., 2011; Kapp, 2012). The definition of gamification recently evolved, focusing on the experiential quality of playing, more than on game design elements (Xi and Hamari, 2019; Hamari, 2019). Its benefits were analysed in several studies that showed how gamification has a positive influence particularly on involvement (Barata et al., 2013; Hamari et al., 2014), motivation (Hamari et al., 2014); (Lister, 2015), outcomes (Lister, 2015), learning (Landers, 2014), participation in lessons or educational activity (Barata et al., 2013; Lister, 2015), satisfaction (Armstrong and Landers, 2018) and entertainment (Lee et al., 2013). This teaching strategy is effective both with typically developing children and with children with Special Educational Needs (Cuschieri et al., 2014; Ifigenia et al., 2018; Dymora and Niemiec, 2019).
In particular, according to the Gamified Learning Theory (Landers, 2014), gamification aims to influence learning behaviours and attitudes through a process of mediation and moderation. Motivation, especially

intrinsic motivation, can be considered as the process that mediates the learning outcomes. and can be investigated on the basis of three primary psychological needs: competence, autonomy and relatedness (Deci and Ryan, 2000)

The experimental training activities of the hereby presented research aimed to evaluate the effectiveness, in terms of motivation, involvement and enhancement of reading and writing skills, of the use of gamified digital software compared to traditional pen-and-paper activities. In particular, two Applications were used, designed to enhance reading and writing skills: Dislessia Evolutiva (Savelli and Pulga, 2016) and Recupero in Ortografia (Ferraboschi and Meini, 2016), along with two exercise books written with the same purpose, Dislessia e trattamento sublessicale (Cazzaniga et al., 2005) and Recupero in ortografia (Ferraboschi and Meini, 2014).

The training of reading and writing skills was proposed to children belonging to a school group (Study A) and children with Specific Learning Disorders (Study B), aged between eight and ten years, attending 3rd, 4th and 5th grade of the Primary School. Furthermore, the school group was also analysed in the subgroups of children with unspecified Neurodevelopmental Disorders and bilingual children.

The intervention activities, performed with the aid of a tablet or computer, and of traditional books, lasted a total of twelve hours.

The research objectives were to assess whether:

1. gamification can lead to better learning outcomes, given by a significant difference in pre- and post-training performances within each condition, and by a significant difference between post-training outcome in different experimental conditions;
2. gamification can motivate and involve students efficiently and effectively during the learning activities.

A statistically significant improvement was reported in most of the reading and writing indices after the training sessions within the school sample, regardless of the type of training. The training performed with the gamified Dislessia Evolutiva software (Savelli and Pulga, 2016) and the manual Dislessia e trattamento sublessicale (Cazzaniga et al., 2005), which propose exercises for the construction and automation of the different reading process components through syllable practice; and gamified training with Recupero in Ortografia (Ferraboschi and Meini, 2016) and traditional one with the manual Recupero in ortografia (Ferraboschi and Meini, 2014), which focus on writing skills enhancement through the improvement of awareness of the most frequent errors, thus increasing the control of the writing processes, determined an intra-individual improvement in performances at post-training (T2) compared to pre-training (T1) results for the different indices of reading and writing skills, with the highest improvement reported for the experimental groups.

Considering what reported by the psychologist Seymour (Vio et al., 2012), who argued that the two skills of reading and writing cannot be completely separated and, therefore, the evolutionary models influence each other, also in this research it was observed that regardless of the skill mainly exercised by the different types of training, there was also an improvement of the other skill.

The results, though, did not show a significantly greater effect of gamification on improvements from pre- to post-training performances than traditional pen-and-paper training. However, as evidenced by the intra-individual analyses, gamified Applications are still a valid tool that can integrate and complement traditional methods during the teaching-learning processes.

Also, for the group of children with Developmental Dyslexia and/or Dysorthography, there was a clinically significant improvement in reading fluency and correctness, and an enhancement, although not significant, in writing accuracy. It is, therefore, possible to state that gamification led to positive results thanks to its use also at the rehabilitation level, with children who had difficulties in school learning.

The difference between school and clinical training consisted in activities that were the same for everyone within the school group, while they were individualised and personalised, based on the individual difficulties reported by the children, for the clinical group, in reading and writing accuracy. Therefore, an individualised approach and the presence of constant educational support are more effective for the enhancement of these skills. It can be deduced that children without school difficulties benefit from gamified activities, even when they are implemented in the same way for everyone. While, for children with greater academic difficulties, there is a need for individualised and personalised programming regarding specific educational needs to make the most of the benefits out of gamification.
In addition, the mediating effect of motivation, in its components of competence, autonomy and relatedness (Deci and Ryan, 2000), on final learning did not emerge. However, the majority of children reported the highest degree of satisfaction in the use of gamified software for the enhancement of reading and writing skills compared to traditional pen-and-paper activities and a general enthusiasm for the proposed activities emerged, as they represented a novelty in comparison to more traditional lessons. Moreover, such enthusiasm and proactivity remained almost unchanged in the experimental groups, whereas, in the subjects assigned to the control conditions, the interest in the proposed activities gradually decreased over time. It was evident how the use of gamified software, which offered a different and innovative teaching method, positively influenced participants' attitude towards the activities, regardless of the effect on performances in the psycholinguistic tests, indicating the importance of a strong game design to provide a captivating and motivating experience.
In conclusion, it is possible to state that the use of gamification, alongside more traditional methodologies and with specific support, can lead to positive improvement effects in learning and motivation, for children with a neurotypical development and children diagnosed with SLD. Furthermore, the hereby presented research proved that a gamified training is feasible both in school and clinical settings, even at home considering that some clinical training sessions took place during health emergency's lockdown.

4.2.1 RESEARCH LIMITS AND FUTURE CONSIDERATIONS

Results must be contextualised in relation to the limits of the research itself.
The first limit is related to the ending questionnaire, as children often showed some difficulties in understanding the proposed questions and asked for frequent clarifications. This, in some way, could have compromised the response trend of individuals, who not always provided accurate answers. Furthermore, the questionnaire was proposed only at the end of the training phase, when it could have proved useful even in the initial phase to subsequently observe the presence of possible differences or significant changes before and after the training activities, to hypothesise a possible mediating effect of the type of training on intrinsic motivation changes. Not less importantly, the students replied to the ending questionnaire in different ways, as the control groups of Study A were given a paper questionnaire whereas all the other groups, both in Study A and Study B, answered it on a digital platform using the tablet. There is no way to determine how the different forms of data collection could have influenced the results; nevertheless, the choice was pondered in order to give continuity to the activities — analog on one hand, digital on the other.
As regards Study A, another limit could be linked to the implementation of the different training programs at school. Although the proposed exercises were appropriate to participants' age and skills (Gee, 2003), and thus produced positive results in terms of performances and involvement, they were not customised on students at the school groups, rather they were the same for all the participants. Therefore, for some students, such activities proved adequate to their abilities, for others they were too simple or complex enough to generate frustration and anxiety. It has also to be mentioned that, even

with the most appreciated gamified activities, some children perceived the training as a mere continuous repetition of exercises. Therefore, a possible improvement in the design of the used Applications or, even, the use of different software, should be considered. All these aspects could have affected the students' well-being — for which data were not collected again at the end of the activities through the QBS questionnaire — their motivation and proactivity, consequently also the post-training performances. Additionally, the books used for the pen-and-paper activities with the control groups also present some elements that could be considered as gamified (i.e., characters, drawings, speech bubbles with feedback, etc.). It is noteworthy to recognise that primary education makes extensive use of analog gamified strategies by default. The main purpose of the research was, then, not to force students to practise on unfamiliar books with no playful elements, rather to explore the potential of digital technologies and gamification to further enhance and develop educational strategies in primary school.

A further limit is linked to the number and distribution of participants as, due to health emergency, students attending the 5th grade of Primary School of one of the Comprehensive Institutes involved, could not take part in post-training data collection conducted with a delay of six months. Therefore, the sample appears to be unbalanced, with a greater number of subjects aged between eight and nine, with the consequent loss of useful data to better assess the effectiveness of gamification on different age groups. Moreover, it would be useful to longitudinally evaluate whether statistically significant improvements in reading and writing skills, that emerged for both types of training, persist even after a long period (indicatively, six months) from the end of the experimental activities, an aspect that, initially, was included within the experimental design but which, due to the health emergency, it was not possible to pursue.

With regard to Study B, a limitation that may have affected research results was the small number of subjects belonging to the clinical group, that is, children with Specific Learning Disorders, and to the school subgroups (unspecified Neurodevelopmental Disorders and bilingualism). In addition to analysing the results of the aforementioned groups in an overall manner, it would have been remarkably interesting to also make a comparison between them based on the gamified Application used during the training, as it was done for the school group.

Also because of the health emergency, the experimental procedures were partially modified. For the clinical group, indeed, some intervention meetings, rather than face-to-face, were performed telematically, through computer screen sharing by the professional. This change has certainly influenced the gaming experience perceived by the user, especially as regards the aspects of autonomy and relatedness. Some children were completely left without supervision at home, and parents reported a change in children's attitude as they easily lost motivation, whereas they seemed to enjoy the sessions with the professionals within the clinical context. Observations that strongly support the role of an adult guiding figure and the fact that, technology alone, cannot be considered sufficient to positively affect improvements (Weisberg et al., 2013).

Finally, considering the need, at the rehabilitation level, of continuous training of difficulties in reading and writing skills and to prevent children to be involved in activities completely different than those proposed by the research, it was decided, together with the psychologists working at the ODFLab, to continue the interventions beyond the twelve hours. However, since the subjects were too few, it was not possible to consider the different ranges of training hours. It would be interesting also to investigate the influence that different hours of training could have on performance improvements, since in the literature there are several studies that indicate an improvement in learning proportional to the hours of intervention (Wanzek and Vaughn, 2008; Locher and Pfost, 2019).

Research on the effectiveness of gamification, however, is constantly evolving, and the hereby presented research has also provided points of reflection for future directions. It would be interesting to investigate the effects of the different types of gamification affordances on changes in intrinsic motivation, thus

identifying specifically which aspects can determine an advantage and which a disadvantage. Future work could include assessment of gamified linguistic interventions in children speaking languages other than Italian, to understand whether benefits are reported also in opaque orthographies. Moreover, as the results showed a promising perspective for individualised training, future research should more carefully address the cognitive profile of each child to better assess the link between linguistic performance improvements and other cognitive aspects.

Gamified Applications seem to have an effectiveness on student performance comparable to traditional pen-and-paper exercises, meaning that both are valid methodologies and that they can be used to support each other. In particular, this new type of digital training can bring important educational advantages for both students and teachers.

In the classroom, the integration of a more traditional method with a digital one could be promoted, and it would allow students to receive immediate and direct feedback on their performance, to have tasks with precise objectives, to learn from their mistakes without fear of judgment. Furthermore, this alternation of teaching methods could have a positive effect on the proactivity and motivation of students, who would feel more immersed in the learning process and encouraged to always pursue better results.

As far as teachers or other professionals are concerned, gamified Applications could offer an integrative tool, not only to achieve the general learning objectives of the entire class group, but also for more specific purposes related to the needs of the individual students or patient, by proposing more targeted exercises to consolidate and enhance any skills. In addition, professionals could also monitor individuals' progress in real time and continue to review the training program. Finally, they would also have a valid tool for distance teaching and/or intervention, essential in the current context. Interestingly, teachers and practitioners' perceptions of the use of gamified Applications at school or in clinical practice could be assessed in comparison to more traditional methodologies, and how this relates to their professional practice and motivation.

The hope is that a shared evidence-based practice can enhance professionals' work and children's learning performances and motivation.

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APPENDIX A

Questionnaire about Gameful Experience and Intrinsic Need Satisfaction

Construct	Item (EN-IT)	Scale (Likert 7)	Dislessia Evolutiva	Recupero in Ortografia	Traditional training
	How much fun did you have playing [APP]? Quanto ti sei divertito a giocare con [APP]?	little/a lot	x	x	x
	Please indicate how much you agree with the following statements, regarding your feelings while using [APP]. Overall, [APP]… *Indica quanto sei d'accordo con le seguenti affermazioni riguardo alle sensazioni che hai provato usando [APP]. In generale, [APP]…*	disagree/agree			
Accomplishment	**Makes me feel that I need to complete things** Mi fa sentire il bisogno di completare l'attività	disagree/agree	x	x	
Accomplishment	**Pushes me to strive for accomplishments** Mi spinge a impegnarmi per avere dei risultati	disagree/agree	x	x	
Accomplishment	**Inspires me to maintain my standards of performance** Mi ispira a mantenere i miei standard di risultato	disagree/agree	x	x	
Accomplishment	**Makes me feel that success comes through accomplishments** Mi fa capire che il successo si ha ottenendo risultati	disagree/agree	x	x	
Accomplishment	**Makes me strive to take myself to the next level** Mi spinge a impegnarmi per raggiungere il livello successivo	disagree/agree	x	x	
Accomplishment	**Motivates me to progress and get better** Mi motiva ad andare avanti e a migliorare	disagree/agree	x	x	

Accomplishment	**Makes me feel like I have clear goals** Mi fa sentire di avere obiettivi chiari	disagree/agree	x	x	
Accomplishment	**Gives me the feeling that I need to reach goals** Mi trasmette la sensazione di dover raggiungere degli obiettivi	disagree/agree	x	x	
Challenge	**Makes me push my limits** Mi spinge a oltrepassare i miei limiti	disagree/agree	x	x	
Challenge	**Drives me in a good way to the brink of wanting to give up** Mi guida positivamente fino al limite del volermi arrendere	disagree/agree	x	x	
Challenge	**Pressures me in a positive way by its high demands** Mi sfida positivamente con un'elevata richiesta	disagree/agree	x	x	
Challenge	**Challenges me** Mi pone delle sfide	disagree/agree	x	x	
Challenge	**Calls for a lot of effort in order for me to be successful** Richiede molti sforzi perché io abbia successo	disagree/agree	x	x	
Challenge	**Motivates me to do things that feel highly demanding** Mi motiva a completare delle attività che sembrano molto impegnative	disagree/agree	x	x	
Challenge	**Makes me feel like I continuously need to improve in order to do well** Mi fa sentire come se avessi continuamente bisogno di migliorare per avere buoni risultati	disagree/agree	x	x	
Challenge	**Makes me work at a level close to what I am capable of** Mi fa lavorare a un livello vicino a ciò di cui sono capace	disagree/agree	x	x	

Competition	**Feels like participating in a competition** Sembra di partecipare a una competizione	disagree/agree	x	x	
Competition	**Inspires me to compete** Mi ispira a competere	disagree/agree	x	x	
Competition	**Involves me by its competitive aspects** Mi coinvolge per i suoi aspetti competitivi	disagree/agree	x	x	
Competition	**Makes me want to be in first place** Mi fa venire voglia di arrivare al primo posto	disagree/agree	x	x	
Competition	**Makes victory feel important** Rende importante la vittoria	disagree/agree	x	x	
Competition	**Feels like being in a race** Sembra di essere in una gara	disagree/agree	x	x	
Competition	**Makes me feel that I need to win to succeed** Mi fa sentire di aver bisogno di vincere per avere successo	disagree/agree	x	x	
Guided	**Makes me feel guided** Mi fa sentire guidato	disagree/agree	x	x	
Guided	**Gives me a sense of being directed** Mi dà la sensazione di essere direzionato	disagree/agree	x	x	
Guided	**Makes me feel like someone is keeping me on track** Mi fa sentire come se qualcuno mi stesse tenendo concentrato sul compito	disagree/agree	x	x	
Guided	**Gives me the feeling that I have an instructor**	disagree/agree	x	x	

	Mi dà la sensazione di avere un insegnante				
Guided	**Gives me the sense I am getting help to be structured** Mi dà la sensazione di ricevere aiuto per essere organizzato	disagree/agree	x	x	
Guided	**Gives me a sense of knowing what I need to do to do better** Mi dà la sensazione di sapere cosa devo fare per migliorare	disagree/agree	x	x	
Guided	**Gives me useful feedback so I can adapt** Mi dà feedback utili per migliorare	disagree/agree	x	x	
Immersion	**Gives me the feeling that time passes quickly** Mi dà la sensazione che il tempo passi rapidamente	disagree/agree	x	x	
Immersion	**Grabs all of my attention** Attira tutta la mia attenzione	disagree/agree	x	x	
Immersion	**Gives me a sense of being separated from the real world** Mi dà la sensazione di essere separato dal mondo reale	disagree/agree	x	x	
Immersion	**Makes me lose myself in what I am doing** Mi fa perdere me stesso in quello che sto facendo	disagree/agree	x	x	
Immersion	**Makes my actions seem to come automatically** Le mie azioni sembrano venire automaticamente	disagree/agree	x	x	
Immersion	**Causes me to stop noticing when I get tired** Mi fa smettere di notare quando sono stanco	disagree/agree	x	x	
Immersion	**Causes me to forget about my everyday concerns** Mi fa dimenticare le mie preoccupazioni quotidiane	disagree/agree	x	x	

Immersion	**Makes me ignore everything around me** Mi fa ignorare tutto ciò che mi circonda	disagree/agree	x	x	
Immersion	**Gets me fully emotionally involved** Mi coinvolge completamente dal punto di vista emotivo	disagree/agree	x	x	
Playfulness	**Gives me an overall playful experience** Mi fa vivere un'esperienza giocosa	disagree/agree	x	x	
Playfulness	**Leaves room for me to be spontaneous** Mi lascia essere spontaneo	disagree/agree	x	x	
Playfulness	**Taps into my imagination** Colpisce la mia immaginazione	disagree/agree	x	x	
Playfulness	**Makes me feel that I can be creative** Mi fa sentire creativo	disagree/agree	x	x	
Playfulness	**Gives me the feeling that I explore things** Mi dà la sensazione di esplorare le cose	disagree/agree	x	x	
Playfulness	**Feels like a mystery to reveal** Sembra che ci sia un mistero da svelare	disagree/agree	x	x	
Playfulness	**Gives me a feeling that I want to know what comes next** Mi dà la sensazione di voler sapere cosa verrà dopo	disagree/agree	x	x	
Playfulness	**Makes me feel like I discover new things** Mi fa sentire come se stessi scoprendo cose nuove	disagree/agree	x	x	
Playfulness	**Appeals to my curiosity** Stimola la mia curiosità	disagree/agree	x	x	

Social experience	**Gives me the feeling that I'm not on my own** Mi dà la sensazione di non essere da solo	disagree/agree	x	x	
Social experience	**Gives me a sense of social support** Mi dà un senso di supporto sociale	disagree/agree	x	x	
Social experience	**Makes me feel like I am socially involved** Mi fa sentire socialmente coinvolto	disagree/agree	x	x	
Social experience	**Gives me a feeling of being connected to others** Mi dà la sensazione di essere collegato agli altri	disagree/agree	x	x	
Social experience	**Feels like a social experience** Sembra un'esperienza comune	disagree/agree	x	x	
Social experience	**Gives me a sense of having someone to Share my endeavors with** Mi dà la sensazione di avere qualcuno con cui condividere i miei sforzi	disagree/agree	x	x	
Social experience	**Influences me through its social aspects** Mi influenza grazie alle sue caratteristiche sociali	disagree/agree	x	x	
Social experience	**Gives me a sense of being noticed for what I have achieved** Mi dà la sensazione di essere notato per quello che ho ottenuto	disagree/agree	x	x	
	Please estimate the average frequency/importance of interacting with the following dimensions of [APP]. *Indica la frequenza con cui interagisci/l'importanza che dai all'interazione con le seguenti dimensioni di [APP].*				
Immersion	**The frequency of interacting with character guide** La frequenza con cui interagisco con il personaggio guida	never/every time	x	x	

Immersion	**The importance of the character guide** L'importanza del personaggio guida	unimportant/ important	x	x	
Immersion	**The frequency of interacting with customisation of avatar** La frequenza con cui interagisco con la personalizzazione dell'avatar	never/every time		x	
Immersion	**The importance of the customisation of avatar** L'importanza della personalizzazione dell'avatar	unimportant/ important		x	
Immersion	**The frequency of interacting with customisation of character guide** La frequenza con cui interagisco con la personalizzazione del personaggio guida	never/every time	x		
Immersion	**The importance of the customisation of character guide** L'importanza della personalizzazione del personaggio guida	unimportant/ important	x		
Immersion	**The frequency of interacting with narrative** La frequenza con cui interagisco con la progressione narrativa	never/every time		x	
Immersion	**The importance of narrative** L'importanza della progressione narrativa	unimportant/ important		x	
Progression	**The frequency of interacting with trophies** La frequenza con cui interagisco con i tesori	never/every time		x	
Progression	**The importance of trophies** L'importanza dei tesori	unimportant/ important		x	
Progression	**The frequency of interacting with the customisation of increasingly difficult tasks**	never/every time	x		

	La frequenza con cui interagisco con la personalizzazione della difficoltà delle attività				
Progression	**The importance of the customisation of increasingly difficult tasks** L'importanza della personalizzazione della difficoltà delle attività	unimportant/ important	x		
Progression	**The frequency of interacting with performance statistics** La frequenza con cui interagisco con le statistiche della mia performance	never/every time	x	x	
Progression	**The importance of performance statistics** L'importanza delle statistiche della mia performance	unimportant/ important	x	x	
Progression	**The frequency of interacting with progress indicators** La frequenza con cui interagisco con l'indicatore di progressione	never/every time	x	x	
Progression	**The importance of progress indicators** L'importanza dell'indicatore di progressione	unimportant/ important	x	x	
Progression	**The frequency of interacting with visual/audio guide feedback** La frequenza con cui interagisco con i feedback visivi/uditivi del personaggio guida	never/every time	x	x	
Progression	**The importance of visual/audio guide feedback** L'importanza dei feedback visivi/uditivi del personaggio guida	unimportant/ important	x	x	
Progression	**The frequency of interacting with retry option** La frequenza con cui interagisco con l'opzione "ripeti"	never/every time	x	x	
Progression	**The importance of retry option** L'importanza dell'opzione "ripeti"	unimportant/ important	x	x	

Social	**The frequency of interacting with competition** La frequenza con cui interagisco con gli aspetti competitivi	never/every time	x	x	
Social	**The importance of competition** L'importanza degli aspetti competitivi	unimportant/ important	x	x	
Prompts	**The frequency of interacting with character guide to receive help** La frequenza con cui interagisco con il personaggio guida per ricevere aiuto	never/every time		x	
Prompts	**The importance of character guide to receive help** L'importanza del personaggio guida per ricevere aiuto	unimportant/ important		x	
Prompts	**The frequency of interacting with lifebelt to receive help** La frequenza con cui interagisco con il salvagente per ricevere aiuto	never/every time	x		
Prompts	**The importance of the lifebelt to receive help** L'importanza del salvagente per ricevere aiuto	unimportant/ important	x		
	For each of the following statements regarding the use of [APP], please indicate how true it is for you. *Per ciascuna delle seguenti affermazioni riguardanti l'uso di [APP], indica quanto è vero per te.*				
Competence	**I think I am pretty good at [APP] activities** Penso di essere abbastanza bravo a svolgere le attività di [APP]	untrue/true	x	x	x
Competence	**I am satisfied with my performance at [APP] tasks** Sono soddisfatto con le mie performance nelle attività di [APP]	untrue/true	x	x	x
Competence	**After working at [APP] activities for a while, I felt pretty competent**	untrue/true	x	x	x

	Dopo essermi esercitato con [APP], mi sento abbastanza competente				
Autonomy	**I believe I had some choice about doing [APP] activities** Credo di aver avuto qualche scelta nel fare le attività di [APP]	untrue/true	x	x	x
Autonomy	**I felt like I had to do [APP] activities (R)** Sento di aver dovuto fare le attività di [APP] (R)	untrue/true	x	x	x
Autonomy	**I did [APP] activities because I wanted to** Ho svolto le attività di [APP] perché lo desideravo	untrue/true	x	x	x
Relatedness	**When I used [APP], I felt supported by my classmates** Quando usavo [APP], mi sentivo supportato dai miei compagni di classe	untrue/true	x	x	x
Relatedness	**When I used [APP], I felt understood by my classmates** Quando usavo [APP], mi sentivo compreso dai miei compagni di classe	untrue/true	x	x	x
Relatedness	**When I used [APP], I felt valued by my classmates** Quando usavo [APP], mi sentivo valorizzato dai miei compagni di classe	untrue/true	x	x	x

APPENDIX B

Activity plan with Dislessia Evolutiva for 3rd class

Activity	2nd session	3rd session	4th session	5th session	6th session	7th session	8th session
Visual discrimination	M-N 120 ms	D-T 120 ms	A-O 120 ms	B-D 120 ms	P-Q 120 ms	I-L 120 ms	F-V 120 ms
Metaphonological analyses	Most used words, 3 letters	Most used words, 4 letters	Reduced dictionary, 4 letters	Reduced dictionary, 5 letters	Reduced dictionary, 5 letters	Complete dictionary, 4 letters	Complete dictionary, 4 letters
Tachistoscope	1.000 most used words, 3 letters 120 ms	Normal words, 4 letters 120 ms	Accented words, 4 letters 120 ms	Words with double letters, 4-5 letters 120 ms	CH group, 3-7 letters 120 ms	GH group, 3-7 letters 120 ms	GL group, 3-7 letters 120 ms
Fast reading	List 1 120 ms	List 5 120 ms	List 10 120 ms	List 15 120 ms	List 20 120 ms	List 25 120 ms	List 30 120 ms
Lexical access	PRO- 5 letters	BAR- 5 letters	CAS- 5 letters	CHI- 5 letters	FRA- 5 letters	RAD- 5 letters	GHE- > 10 letters
Cloze reading	L'asino e il lupo 3 prompts	L'albero nuvola 3 prompts	La scure perduta 2 prompts	Il falcone e l'anatra 3 prompts	Il furbo ladro di cavalli 2 prompts	Lo scienziato contadino 3 prompts	Le avventure di Jim Bottone 3 prompts
Naming	Various words	Various words	Various words	Various words	Various words	Various words	Various words
Syllabic naming	Various words 3 syllables no distractors	Various words 3 syllables no distractors	Various words 3 syllables no distractors	Various words 3 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors

Orthographic prediction	Various words	Various words	Various words	Various words	Various words	Various words	Various words

Activity	9th session	10th session	11th session	12th session	13th session	14th session	15th session
Visual discrimination	P-B 120 ms	M-N 120 ms	D-T 120 ms	S-Z 120 ms	B-D 120 ms	U-V 120 ms	P-B 120 ms
Metaphonological analyses	Complete dictionary, 5 letters	Complete dictionary, 5 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters
Tachistoscope	SC group, 3-7 letters 120 ms	SCE group, 3-7 letters 120 ms	SCI group, 3-7 letters 120 ms	QU-CU group, 3-7 letters 20 ms	SCA-SCO group, 3-7 letters 120 ms	Non words, 4 letters 120 ms	1.000 most used words, 6 letters 120 ms
Fast reading	List 35 120 ms	List 40 120 ms	List 45 120 ms	List 50 120 ms	List 55 120 ms	List 60 120 ms	List 65 120 ms
Lexical access	SCI- 6 letters	SCE- 7 letters	CAN- 7 letters	CHI- 7 letters	GHI- 7 letters	SVE- 8 letters	SFA- 8 letters
Cloze reading	Storia della bicicletta verde 3 prompts	Il grande ascensore di cristallo 3 prompts	Le ostriche per il cavallo 3 prompts	Il segreto della casa sul cortile 3 prompts	Moby Dick 3 prompts	La prima poesia di pablo Neruda 3 prompts	Il sognatore 3 prompts
Naming	Various words	Various words	House related words	House related words	House related words	Food related words	Animals related words
Syllabic naming	Various words	Various words	Animals related	Animals related	Animals related	House related	Food related

	4 syllables with distractors	4 syllables with distractors	words 4 syllables with distractors	words 4 syllables with distractors	words 3 syllables with distractors	words 3 syllables with distractors	words 3 syllables with distractors
Orthographic prediction	Various words	Various words	Food related words	Food related words	Food related words	Animals related words	House related words

Activity plan with Dislessia Evolutiva for 4th class

Activity	2nd session	3rd session	4th session	5th session	6th session	7th session	8th session
Visual discrimination	M-N 100 ms	D-T 100 ms	A-O 100 ms	B-D 100 ms	P-Q 100 ms	I-L 100 ms	F-V 100 ms
Metaphonological analyses	Reduced dictionary, 4 letters	Reduced dictionary, 5 letters	Complete dictionary, 5 letters	Complete dictionary, 5 letters	Complete dictionary, 5 letters	Complete dictionary, 5 letters	Complete dictionary, 5 letters
Tachistoscope	1.000 most used words, 4 letters 100 ms	Normal words, 5 letters 100 ms	Accented words, 5 letters 100 ms	Words with double letters, 4-5 letters 100 ms	CH group, 3-7 letters 100 ms	GH group, 3-7 letters 100 ms	GL group, 3-7 letters 100 ms
Fast reading	List 1 100 ms	List 5 100 ms	List 10 100 ms	List 15 100 ms	List 20 100 ms	List 25 100 ms	List 30 100 ms
Lexical access	PRO- 5 letters	BAR- 5 letters	CAS- 5 letters	CHI- 5 letters	FRA- 5 letters	RAD- 6 letters	GHE- > 10 letters
Cloze reading	L'asino e il lupo 3 prompts	L'albero nuvola 3 prompts	La scure perduta 3 prompts	Il falcone e l'anatra	Il furbo ladro di cavalli	Lo scienziato contadino	Le avventure di Jim Bottone

				3 prompts	3 prompts	3 prompts	3 prompts
Naming	Various words	Various words	Various words	Various words	Various words	Various words	Various words
Syllabic naming	Various words 3 syllables no distractors	Various words 3 syllables no distractors	Various words 3 syllables no distractors	Various words 3 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors
Orthographic prediction	Various words	Various words	Various words	Various words	Various words	Various words	Various words

Activity	9th session	10th session	11th session	12th session	13th session	14th session	15th session
Visual discrimination	P-B 100 ms	M-N 100 ms	D-T 100 ms	S-Z 100 ms	B-D 100 ms	U-V 100 ms	P-B 100 ms
Metaphonological analyses	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 7 letters	Complete dictionary, 7 letters	Complete dictionary, 7 letters
Tachistoscope	SC group, 3-7 letters 120 ms	SCE group, 3-7 letters 120 ms	SCI group, 3-7 letters 120 ms	QU-CU group, 3-7 letters 20 ms	SCA-SCO group, 3-7 letters 120 ms	Non words, 4 letters 120 ms	1.000 most used words, 6 letters 120 ms
Fast reading	List 35 100 ms	List 40 100 ms	List 45 100 ms	List 50 100 ms	List 55 100 ms	List 60 100 ms	List 65 100 ms
Lexical access	SCI- 6 letters	SCE- 7 letters	CAN- 7 letters	CHI- 7 letters	GHI- 7 letters	SVE- 8 letters	SFA- 8 letters
Cloze reading	Storia della	Il grande	Le ostriche per il	Il segreto della	Moby Dick	La prima poesia	Il sognatore

	bicicletta verde 3 prompts	ascensore di cristallo 3 prompts	cavallo 3 prompts	casa sul cortile 3 prompts	3 prompts	di pablo Neruda 3 prompts	3 prompts
Naming	Various words	Various words	House related words	House related words	House related words	Food related words	Animals related words
Syllabic naming	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Animals related words 4 syllables with distractors	Animals related words 4 syllables with distractors	Animals related words 3 syllables with distractors	House related words 3 syllables with distractors	Food related words 3 syllables with distractors
Orthographic prediction	Various words	Various words	Food related words	Food related words	Food related words	Animals related words	House related words

Activity plan with Dislessia Evolutiva for 5th class

Activity	2nd session	3rd session	4th session	5th session	6th session	7th session	8th session
Visual discrimination	M-N 80 ms	D-T 80 ms	A-O 80 ms	B-D 80 ms	P-Q 80 ms	I-L 80 ms	F-V 80 ms
Metaphonological analyses	Complete dictionary, 4 letters	Complete dictionary, 5 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 5 letters
Tachistoscope	1.000 most used words, 4 letters 80 ms	Normal words, 5 letters 80 ms	Accented words, 5 letters 80 ms	Words with double letters, 4-5 letters 80 ms	CH group, 3-7 letters 80 ms	GH group, 3-7 letters 80 ms	GL group, 3-7 letters 80 ms

Fast reading	List 1 80 ms	List 5 80 ms	List 10 80 ms	List 15 80 ms	List 20 80 ms	List 25 80 ms	List 30 80 ms
Lexical access	PRO- 5 letters	BAR- 5 letters	CAS- 5 letters	CHI- 5 letters	FRA- 5 letters	RAD- 5 letters	GHE- > 10 letters
Cloze reading	L'asino e il lupo 3 prompts	L'albero nuvola 3 prompts	La scure perduta 2 prompts	Il falcone e l'anatra 3 prompts	Il furbo ladro di cavalli 2 prompts	Lo scienziato contadino 3 prompts	Le avventure di Jim Bottone 3 prompts
Naming	Various words	Various words	Various words	Various words	Various words	Various words	Various words
Syllabic naming	Various words 3 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Various words 4 syllables with distractors
Orthographic prediction	Various words	Various words	Various words	Various words	Various words	Various words	Various words

Activity	9th session	10th session	11th session	12th session	13th session	14th session	15th session
Visual discrimination	P-B 80 ms	M-N 80 ms	D-T 80 ms	S-Z 80 ms	B-D 80 ms	U-V 80 ms	P-B 80 ms
Metaphonological analyses	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 6 letters	Complete dictionary, 7 letters	Complete dictionary, 7 letters	Complete dictionary, 7 letters
Tachistoscope	SC group, 3-7 letters 80 ms	SCE group, 3-7 letters 80 ms	SCI group, 3-7 letters 80 ms	QU-CU group, 3-7 letters 80 ms	SCA-SCO group, 3-7 letters 80 ms	Non words, 4 letters 80 ms	1.000 most used words, 6 letters 80 ms

Fast reading	List 35 80 ms	List 40 80 ms	List 45 80 ms	List 50 80 ms	List 55 80 ms	List 60 80 ms	List 65 80 ms
Lexical access	SCI- 6 letters	SCE- 7 letters	CAN- 7 letters	CHI- 7 letters	GHI- 7 letters	SVE- 8 letters	SFA- 8 letters
Cloze reading	Storia della bicicletta verde 3 prompts	Il grande ascensore di cristallo 3 prompts	Le ostriche per il cavallo 3 prompts	Il segreto della casa sul cortile 3 prompts	Moby Dick 3 prompts	La prima poesia di pablo Neruda 3 prompts	Il sognatore 3 prompts
Naming	Various words	Various words	House related words	House related words	House related words	Food related words	Animals related words
Syllabic naming	Various words 4 syllables with distractors	Various words 4 syllables with distractors	Animals related words 4 syllables with distractors	Animals related words 4 syllables with distractors	Animals related words 3 syllables with distractors	House related words 3 syllables with distractors	Food related words 3 syllables with distractors
Orthographic prediction	Various words	Various words	Food related words	Food related words	Food related words	Animals related words	House related words

APPENDIX C

Activity plan with Recupero in Ortografia for 3rd class

1st map	2nd map	3rd map	4th map
F/V - Listen to words starting with F	INVERSION - Search for UN among letters	OMISSION/ADDITION - Rearrange letters	OMISSION/ADDITION - Rearrange letters
F/V - Figures starting with F	INVERSIONS - Sentences with errors	GN - Complete words in sentences	INVERSION - Chronological order of

			actions
F/V - Pairs of similar words	GN - Figures with GN	SCI/SCE - Figures with SCI/SCE	F/V - Choose the correct word
F/V - Choose the correct word	GN - Search for words with GN	DOUBLE - Listen to words with and without double letters	D/T - Complete words in sentences
F/V - Complete words in sentences	GN - Complete words in sentences	GLI - Complete words with GLI/LI	P/B - Listen to words containing P
D/T - Listen to words starting with D	SCI/SCE - Listen to words with SCI/SCE	CHI - Listen to words with CHI	ACCENT - Accent words in sentences
D/T - Figures starting with T	SCI/SCE - Figures with SCI/SCE	CHI - Figures with CHI	APOSTROPHE - Sentences with errors
D/T - Pairs of similar words	SCI/SCE - Complete words with SI/SCI	CHI - Search for words with CHI	H - Choice between A and HA in text
D/T - Choose the correct word	SCI/SCE - Complete words with SCE/SCIE	CHI - Complete words with CI/CHI	H - Choice of correct sentence
D/T - Complete words in sentences	SCI/SCE - Sentences with errors	CHI - Complete words with GI/GHI	GRAPHEMES - Complete words in sentences
P/B - Listen to words containing P	SEPARATION/FUSION - Count words in sentences	ACCENT - Listen to accented words	GLI - Complete words with GLI/LI
P/B - Figures starting with P	SEPARATION/FUSION - Insert words into boxes	ACCENT - Choice of words with correct accent	GLI - Sentences with errors
P/B - Pairs of similar words	DOUBLE - Complete nursery rhymes	ACCENT - Accent words in sentences	CHI - Listen to words with CHI
P/B - Choose the correct word	DOUBLE - Listen to words with double letters	APOSTROPHE - Apostrophe between article and word	CHI - Sentences with errors
P/B - Complete words in sentences	DOUBLE - Listen to words with and	APOSTROPHE - Rewrite words with	ACCENT - Listen to accented words

	without double letters	apostrophe	
OMISSION/ADDITION - Words in boxes	GLI - Listen to words with GLI	H - Choice between A and HA in sentences	GN - Sentences with errors
OMISSION/ADDITION - Similar words, different images	GLI - Figures with GLI	H - Choice of correct sentence	SCI/SCE - Sentences with errors
OMISSION/ADDITION - Write figure names	GLI - Search for words with GLI	H - Sentences with errors	SCI/SCE - Complete words with SI/SCI
OMISSION/ADDITION - Rearrange letters	GLI - Complete words with GLI/LI	GRAPHEMES - Discrimination of words with CU, QU, CQU, CCU	SEPARATION - Riddles
OMISSION/ADDITION - Sentences with errors	GLI - Complete words in sentences	GRAPHEMES - Matching scenes and words	DOUBLE - Text with errors

Activity plan with Recupero in Ortografia for 4th class

1st map	2nd map	3rd map	4th map
F/V - Listen to words starting with F	INVERSION - Search for CAR among letters	OMISSION/ADDITION - Rearrange letters	GN - Sentences with errors
F/V - Figures containing F	INVERSIONS - Sentences with errors	GN - Complete words in sentences	SCI/SCE - Figures with SCI/SCE
F/V - Pairs of similar words	GN - Figures with GN	SCI/SCE - Figures with SCI/SCE	SCI/SCE - Search for words with SCI/SCE
F/V - Choose the correct word	GN - Search for words with GN	DOUBLE - Listen to words with and	SEPARATION - Separate words in

		without double letters	sentences
F/V - Complete words in sentences	GN - Complete words in sentences	GLI - Complete words with GLI/LI	DOUBLE - Words in rebus
D/T - Listen to words starting with D	SCI/SCE - Listen to words with SCI/SCE	CHI - Listen to words with CHI	OMISSION/ADDITION - Crossword
D/T - Figures starting with T	SCI/SCE - Search for words with SCI/SCE	CHI - Figures with CHI	INVERSION - Words and temporal order
D/T - Pairs of similar words	SCI/SCE - Complete words with SI/SCI	CHI - Search for words with CHI	F/V - Complete words in sentences
D/T - Choose the correct word	SCI/SCE - Complete words with SCE/SCIE	CHI - Complete words with CI/CHI	D/T - Choose the correct word
D/T - Complete words in sentences	SCI/SCE - Sentences with errors	CHI - Complete words with GI/GHI	P/B - Complete words in sentences
P/B - Listen to words containing P	SEPARATION/FUSION - Count words in sentences	ACCENT - Listen to accented words	APOSTROPHE - Apostrophe between article and word
P/B - Figures starting with P	SEPARATION/FUSION - Insert words into boxes	ACCENT - Choice of words with correct accent	APOSTROPHE - Apostrophe between preposition and word
P/B - Pairs of similar words	DOUBLE - Completing nursery rhymes	ACCENT - Accent words in sentences	H - Verb in perfect past tense
P/B - Choose the correct word	DOUBLE - Listen to words with double letters	APOSTROPHE - Apostrophe in sentences	H - Sentences with errors
P/B - Complete words in sentences	DOUBLE - Listen to words with and without double letters	APOSTROPHE - Rewrite words with apostrophe	GRAPHEMES - Complete words with CU, QU, CQU, CCU
OMISSION/ADDITION - Words in boxes	GLI - Listen to words with GLI	H - Choice between A and HA in sentences	GN - Sentences with errors

OMISSION/ADDITION - Similar words, different images	GLI - Figures with GLI	H - Choice of correct sentence	SCI/SCE - Sentences with errors
OMISSION/ADDITION - Write figure names	GLI - Search for words with GLI	H - Sentences with errors	SCI/SCE - Complete words with SI/SCI
OMISSION/ADDITION - Rearrange letters	GLI - Complete words with GLI/LI	GRAPHEMES - Discrimination of words with CU, QU, CQU, CCU	SEPARATION - Riddles
OMISSION/ADDITION - Sentences with errors	GLI - Complete words in sentences	GRAPHEMES - Matching scenes and words	DOUBLE - Text with errors

Activity plan with Recupero in Ortografia for 5th class

1st map	2nd map	3rd map	4th map
F/V - Listen to words starting with F	INVERSION - Search for BURN among letters	OMISSION/ADDITION - Rearrange letters	GLI - Complete words with GLI/LI
F/V - Listen to words containing F	INVERSION - Sentences with errors	GN - Complete words in sentences	GLI - Complete words in sentences
F/V - Pairs of similar words	GN - Figures with GN	SCI/SCE - Figures with SCI/SCE	CHI - Complete words with CI/CHI
F/V - Choose the correct word	GN - Search for words with GN	DOUBLE - Listen to words with and without double letters	CHI - Complete words with GI/GHI
F/V - Complete words in sentences	GN - Complete words in sentences	GLI - Complete words with GLI/LI	ACCENT - Choice of words with correct accent
D/T - Listen to words starting with D	SCI/SCE - Listen to words with SCI/SCE	CHI - Listen to words with CHI	GN - Search for words with GN

D/T - Figures containing T	SCI/SCE - Search for words with SCI/SCE	CHI - Search for words with CHI	SCI/SCE - Complete words with SI/SCI
D/T - Pairs of similar words	SCI/SCE - Complete words with SI/SCI	CHI - Complete words with CI/CHI	SCI/SCE - Complete words with SCE/SCI
D/T - Choose the correct word	SCI/SCE - Complete words with SCE/SCIE	CHI - Complete words with GI/GHI	SEPARATION - Listen to sentences and counting words number
D/T - Complete words in sentences	SCI/SCE - Sentences with errors	CHI - Sentences with errors	DOUBLE - Text with errors
P/B - Listen to words containing P	SEPARATION/FUSION - Count words in sentences	ACCENT - Listen to accented words	OMISSION/ADDITION - Sentences with errors
P/B - Figures containing P	SEPARATION/FUSION - Insert words into boxes	ACCENT - Choice of words with correct accent	INVERSION - Sentences with errors
P/B - Pairs of similar words	DOUBLE - Completing nursery rhymes	ACCENT - Accent words in nursery rhymes	F/V - Complete words in sentences
P/B - Choose the correct word	DOUBLE - Listen to words with double letters	APOSTROPHE - Apostrophe between preposition and word	D/T - Complete words in sentences
P/B - Complete words in sentences	DOUBLE - Text with errors	APOSTROPHE - Rewrite words with apostrophe	P/B - Complete words in sentences
OMISSION/ADDITION - Words in boxes	GLI - Listen to words with GLI	H - Choice between A and HA in text	GN - Sentences with errors
OMISSION/ADDITION - Similar words, different images	GLI - Figures with GLI	H - Choice of correct sentence	SCI/SCE - Sentences with errors

OMISSION/ADDITION - Write figure names	GLI - Search for words with GLI	H - Text with errors	SCI/SCE - Complete words with SI/SCI
OMISSION/ADDITION - Rearrange letters	GLI - Complete words in sentences	GRAPHEMES - Complete words with CU, QU, CQU, CCU	SEPARATION - Riddles
OMISSION/ADDITION - Sentences with errors	GLI - Sentences with errors	GRAPHEMES - Matching scenes and words	DOUBLE - Text with errors

APPENDIX D

Activity plan with Dislessia e trattamento sublessicale textbook

Session	3rd class	4th class	5th class
1st	Syllables reading and division, CI group, words play	Syllables reading and division, CI group, words play	Syllables reading and division, CI group, words play
2nd	Syllables reading and division, CHI group	Syllables reading and division, CHI group	Syllables reading and division, CHI group
3rd	Syllables reading and division, CHE group, words play	Syllables reading and division, CHE group, words play	Syllables reading and division, CHE group, words play
4th	Syllables reading and division, CE group	Syllables reading and division, CE group	Syllables reading and division, CE group
5th	Syllables reading and division, GI group, words composition	Syllables reading and division, GI group, words composition	Syllables reading and division, GI group, words composition
6th	Syllables reading and division, GHI group	Syllables reading and division, GHI group	Syllables reading and division, GHI group
7th	Syllables reading and division, GE group, words composition	Syllables reading and division, GE group, words composition	Syllables reading and division, GE group, words composition
8th	Syllables reading and division, GHE group	Syllables reading and division, GHE group	Syllables reading and division, GHE group
9th	Syllables reading and division, SCE group	Syllables reading and division, SCE group	Syllables reading and division, SCE group
10th	Syllables reading and division, SCI group, words recognition	Syllables reading and division, SCI group, words recognition	Syllables reading and division, SCI group, words recognition
11th	Syllables reading and division, GLI group	Syllables reading and division, GLI group	Syllables reading and division, GLI group

12th	Syllables reading and division, GN group	Syllables reading and division, GN group	Syllables reading and division, GN group
13th	Syllables reading, words composition	Syllables reading, words composition	Syllables reading, words composition
14th	Syllables division, words composition	Syllables division, words composition	Syllables division, words composition
15th	Words composition and recognition	Words composition and recognition	Words composition and recognition

APPENDIX E

Activity plan with Recupero in Ortografia textbook

Session	3rd class	4th class	5th class
1st	F/V discrimination	F/V discrimination	F/V discrimination
2nd	D/T discrimination	D/T discrimination	D/T discrimination
3rd	P/B discrimination	P/B discrimination	P/B discrimination
4th	Letters omission/addition	Letters omission/addition	Letters omission/addition
5th	Inversions, GN group	Inversions, GN group	Inversions, GN group
6th	SCI-SCE groups	SCI-SCE groups	SCI-SCE groups
7th	Fusions and illegal separations, double letters	Fusions and illegal separations, double letters	Fusions and illegal separations, double letters
8th	GLI group	GLI group	GLI group
9th	Double letters, SCI-SCE groups review	Double letters, SCI-SCE groups review	Double letters, SCI-SCE groups review
10th	CHI-CHE groups	CHI-CHE groups	CHI-CHE groups
11th	Apostrophe, accents	Apostrophe, accents	Apostrophe, accents
12th	Use of H	Use of H	Use of H
13th	Exchange of homophone, not homograph grapheme	Exchange of homophone, not homograph grapheme	Exchange of homophone, not homograph grapheme
14th	Graphemes exchange, letters omission/addition	Graphemes exchange, letters omission/addition	Graphemes exchange, letters omission/addition

15th	CE/GE and CI/GI discrimination	CE/GE and CI/GI discrimination	CE/GE and CI/GI discrimination