Applying Memory Theory in Game Design (Case Study)

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Abstract: This article reflects upon the design process of the game Tella, an application for tablet computers, designed for children with special needs in the lowest grades at school. The game facilitates learning of mathematics through playing and exploring. The tablet allows the visual and interaction design to work together with sound and movement, in ways that differs from traditional learning material and classroom practices, supplementing both these arenas of learning. Several different pedagogical principles are applied in the game. This article will focus on the concept of *implicit memory / priming*: Elements (e.g. the number line) are introduced visually at an early stage, but not put into practical use until later in the game. Priming is a concept from the field of memory research, not a pedagogical principle or a learning theory as such, but in connection with designing games this concept is applicable and very helpful. Further on this article reflects upon the balance between game logic and learning logic, when designing serious games. There are contradictions that need to be negotiated if an application should serve as an e-learning resource as well as an enjoyable game. The article suggests a way of developing educational games. The design of the game started by having experienced teachers sit down and work with designers and game programmers. The result incorporate theories and principles of learning, memory, game design and instructional design.

Keywords: serious games, learning, priming, design

1. This is TELLA

Tella is a game of mathematics, designed for children with learning disabilities in the lowest grades at school, also aiming at normally functioning children of lower age, from three years on. The visual and instructional design is made to be appealing and motivating, to encourage children to play.

When planning the design we had a list of challenges:

- Teach mathematics, helping children build basic understanding of some crucial concepts, connections and operations.
- Facilitate basic digital competence.
- Make maths fun and appealing for children with learning disabilities (motivation).
- Make it possible for these children to feel mastery on a field where they usually have little success.
- Facilitate individualized instruction in groups (classes) so that children may work/play on different learning levels without leaving their class, which will have a social integrative effect.
- Be a tool for teachers who want variation of methods in their teaching.
- Be a tool with connections to other learning material (like text books) and physical/tactical/motoric learning situations.

We do emphasize that digital learning can not fully replace traditional types of learning in mathematics: In order to learn children need to apply most senses. Tactical and motoric stimulation are crucial, and such activities are not afforded adequately by a screen alone.

Tella consists of several modules (levels) with tasks to be completed in a predefined order. The structure of the game and the learning has been carefully planned with a slow progression, each level building on the previous. The teacher may customize the game for each pupil individually by making tasks invisible. Thus it is possible for a child to achieve mastery even if he does not have access to all tasks.

The game begins with building awareness of size and position/order/ranking. Then follow counting, figures, numbers and quantities up to nine. The number line is gradually introduced. (Number line is important to understand the relationship between numbers and ranking.) The final levels of the game offer tasks with simple equations.

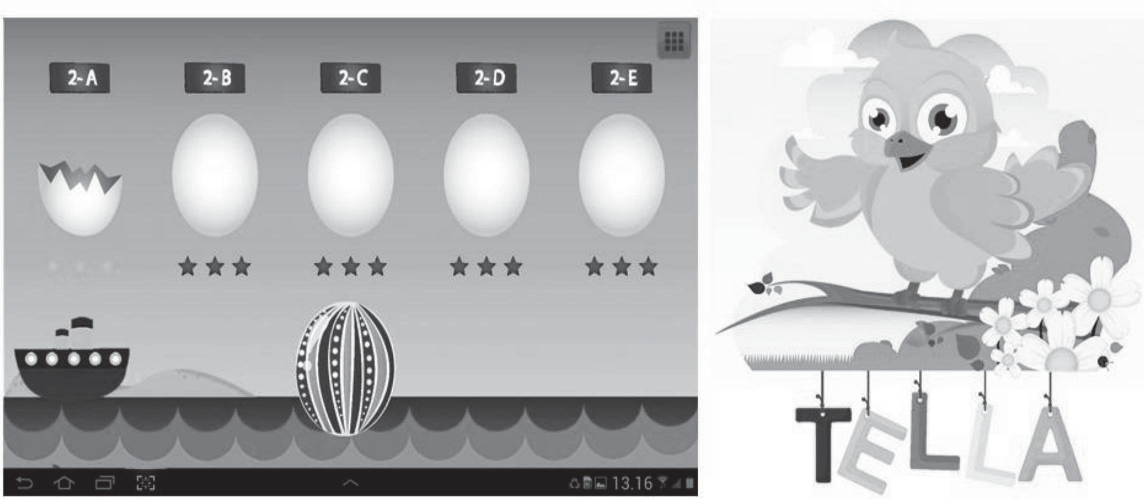

Figure 1: The yellow bird is the helper, and tasks are presented as eggs

Recommended playing time is maximum 30 minutes at a time, and teachers are advised to elaborate the different themes of the game in “real world” surroundings, motivating the children to practice counting and playing with numbers in an everyday context.

2. Implicit memory and priming

When designing Tella we have applied principles of memory and learning. Among those *implicit memory/priming*. Implicit memory, as opposed to explicit memory, “occurs when memory influences our behavior without conscious awareness” (Passer & Smith 2011, p 266). This relates to the process of priming, where “exposure to a stimulus influences (i.e., primes) how you subsequently respond to that same or another stimulus.” (Passer & Smith 2011, p 178). By introducing phenomena visually without problematizing them, the game prepares the child for the conscious handling, which will be demanded later.

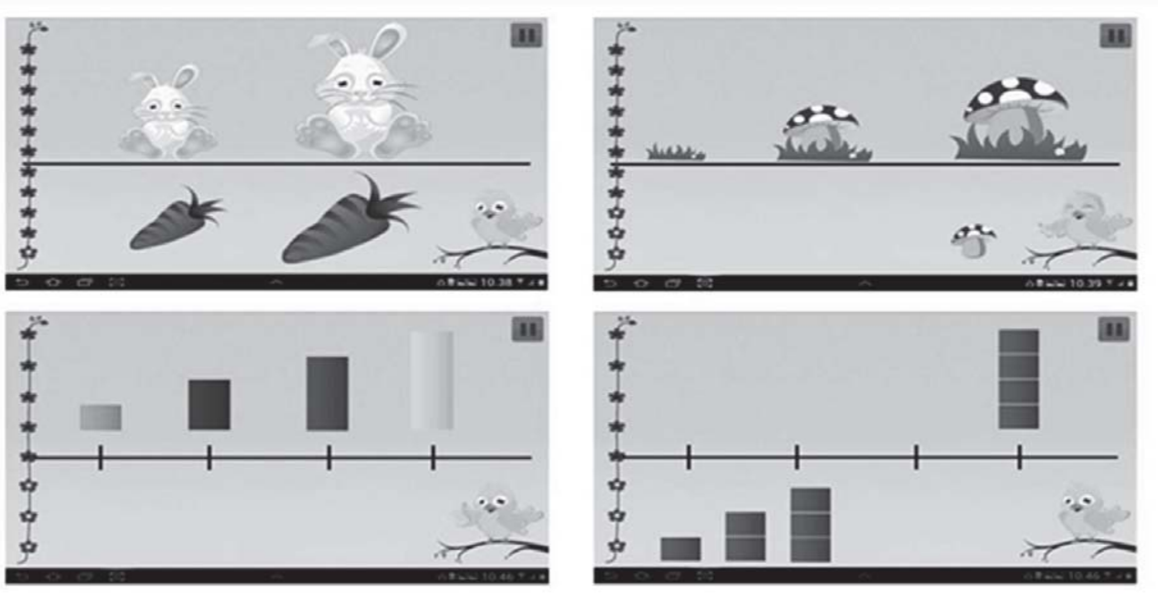

Figure 2: The child learns to range objects according to size. The smallest object is always to the left, to prepare for the understanding of number lines

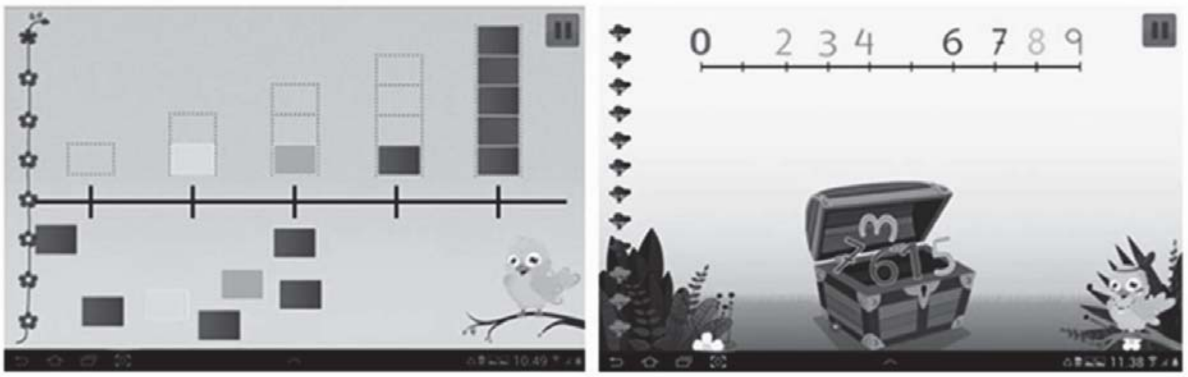

Figure 3: Building quantities to prepare for the understanding of numbers, then working/playing with the number line

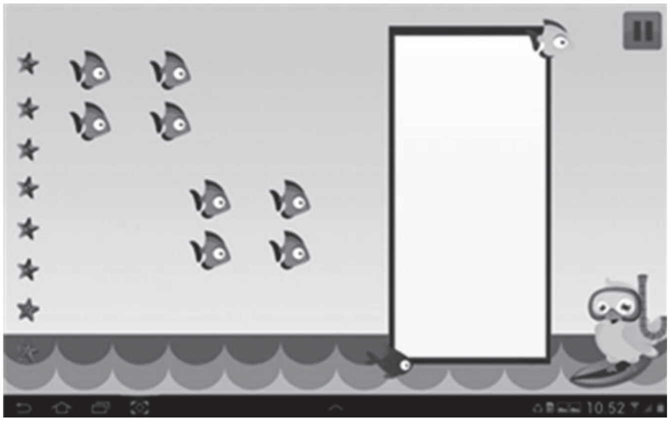

Figure 4: The objects that have to be counted are shown in patterns/quantities. Note how the eight fish are divided into four plus four, preparing the child to later addition

3. Theories of learning

The game Tella is also drawing on *instant feedback and reward*. This is based on classical behaviourism and stimulus-response models, and is a common base for a lot of small main stream games as well as serious (pedagogical) games. Having given an answer to a question or a task, the child gets immediate response by means of sound and the bird's approval. There is also a "not so immediate" response as the player's collection of stars increases. The stimulus-response theory and the concept of implicit memory also shed light on how children "automate" some patterns of behaviour. *Automaticity* of certain tasks are vital when performing mathematical tasks - one cannot contemplate all the logic behind every step in a mathematical task, but has to rely largely on an "automated" set of basic skills (Hasselbring, 1988).

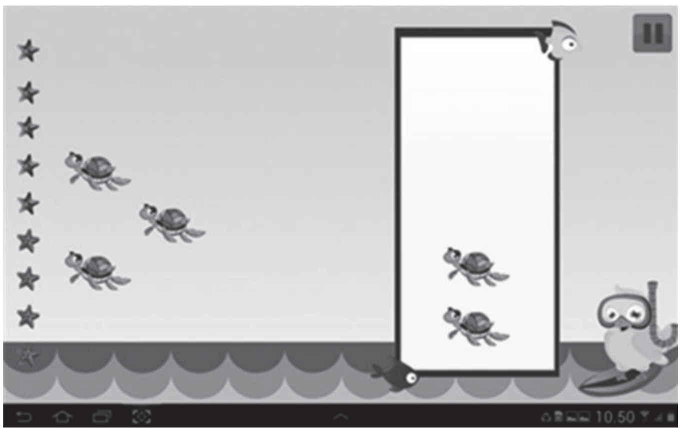

Figure 5: Automation of counting is learned by small children long before they are capable of understanding quantities and numbers. The bird is counting out loud together with the child here (auditive input)

The game may be regarded as a partner to the learning child. Therefore it becomes important how features of different game mechanics may influence on the individual's reasoning (Arnseth, 2006). This makes some aspects of socio-cultural learning theory relevant, where learning is understood as a close interplay between human actors and artefacts. The introduction of new concepts, in a specific order, can here be seen in light of the *theory of "Zone of Proximal Development"* (Vygotsky, 1930). Vygotsky's theories were developed from observing how small children expand their capacities when interacting with others. Vygotsky defined the "Zone of Proximal Development" as the difference between the level that the child can develop by independent problem solving and their potential level of development. Children can reach higher levels when collaborating with others, where the Zone of Proximal Development can be seen as a bridge between the individual learner and their cultural environment (Erstad, 2001). As computer games are among the significant artefacts in the culture surrounding many children, and moderate gaming in may give a positive contribution to the development of children's skills and knowledge (Przybylski, 2014).

4. Gaming logic versus pedagogical logic

A significant challenge is to design games that give the players proper and interesting challenges (Egenfeldt-Nielsen, 2011). This is a difficult design issue in its own right, which becomes even more complex when taking wanted learning outcomes into account.

In game design it is considered vital to keep the player in "the zone" where he experiences "flow". The concept of flow is used to explain how joy or happiness can emerge from activities where the player is experiencing total involvement (Csikzentmihalyi 1992, 71). This concerns the level of complexity and difficulty of the tasks being sufficient to keep the player engaged. We are not talking about "zone " in Vygotsky's sense, but the two concepts are somewhat related. A wanted outcome in game design is to bring the player into short periods of frustration, where he struggles to solve the problems presented to him, then provide the feeling of accomplishment, and thereby keep up the player's engagement. With the helper always present within the game, and a teacher at hand, pupils with difficulties can be kept in this dual zone, where they are constantly challenged and rewarded by mastering series of different tasks.

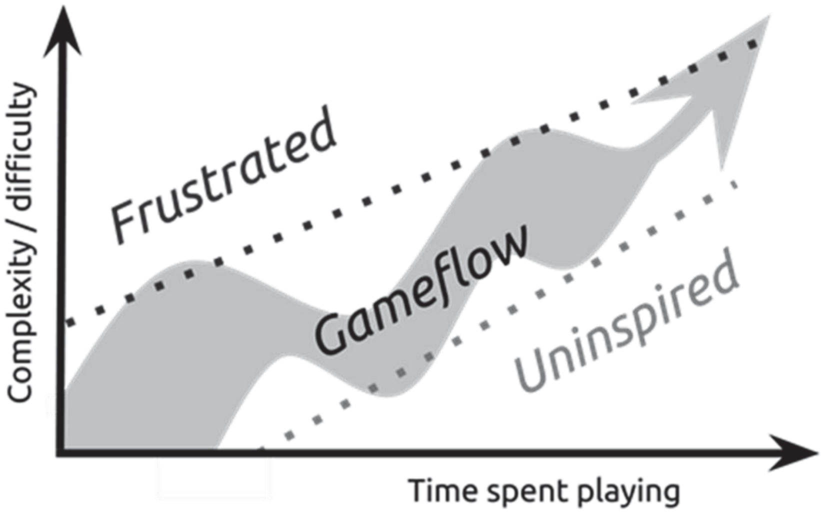

Figure 6: The "zone", between frustration and activities that the player find uninspiring, where the players are in the "flow"

Players are of course different, and it is hardly possible to design tasks that give all users the same level of engagement. It is not possible to design for a specific level of difficulty that also keep every player engaged at all times. This becomes even more difficult when designing a game for pupils with special needs. Many of these players may have problems concentrating, and easily become distracted. If they become frustrated or uninspired they tend to look for something else to do. Thus it becomes important to keep these players within the engaged-zone as much as possible during their gaming time.

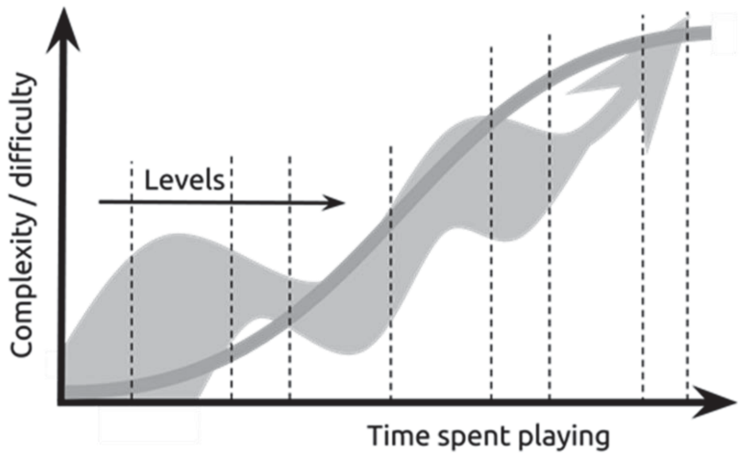

Figure 7: A game for users with special needs to keep the technical challenges at an almost even level throughout the game. The orange line indicated the level of mathematical complexity, which increases throughout the game with each level. The complexity of the game mechanics do, however, not increase in a similar way. The tasks do become somewhat more complex, but most are managed with relatively simple point, drag and drop

5. Conclusions and further work

We have discussed some theoretical approaches, which were present in the process designing Tella. However, the theoretical approach was not the starting point when the design was initially planned. Experienced teachers' knowledge was used in interplay with experience from game designers, instructional - and visual designers. The result has become a game that may not fulfill every game design rule, but the result is grounded in knowledge about learning and memory.

Our preliminary conclusions draws on experiences from field testing and user feedback. This emphasizes the importance of collaboration between teachers, designers and programmers. Each of these collaborators bring in expertise crucial to a successful game: It is necessary to know what is going on in a classroom, how children learn and play, how visual elements can be explanatory and carry meaning and motivation, how games are structured to make the player want to go on pursuing a goal, what affordances and limits are set by technical devices, and so on.

The work with Tella demonstrates how learning principles can be applied to game design. Further work and research will seek to provide a more thorough analysis of the game and how it is used. This will include field testing to investigate how the game is used, and to what extent the game is being regarded as useful in real educational contexts. This testing will include observation, structured interviews with teachers and group interviews with children.

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