How to design a digital individual learning RCT-study in the context of the Swedish preschool: experiences from a pilot-study

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ABSTRACT
This article takes its point of departure in the research methodology of a comprehensive and multi-disciplinary innovative intervention study in Swedish preschools with preschoolers aged 3–5, involving two digital learning games focusing early math and executive functions. Based on a combination of video-ethnography, focus groups, field notes and digital progression log data, the analysis of a pilot study of the pedagogical intervention challenges and extends theoretical and methodological perspectives on what it means to undertake an intervention study in this context. The aim is to discuss what a mixed-methods research approach may provide for the understanding of intervention methodology by illustrating how different types of data provide understandings of how and to what extent the intervention components are functional in the pedagogical setting. The conclusion the analysis supports is that unless children’s and preschool teachers’ meaning making of the unfolding actions in the digital interface make them engage in the activity and dynamically fits within the institutional preschool system, the intervention will not be functional. A pilot study can provide detailed understandings of why, how and in what contexts interventions as part of the dynamic preschool systems can be implemented with adherence and fidelity.

Introduction
The quest to describe, explain, and promote educational practice in favour of each child’s development and learning through evidence-based knowledge, is a high priority. The reliance on evidence-based practice has grown and spread from the US to Europe and Australia (Peterson 2016), and now also to the arena of the Swedish preschool. The study of effects of pedagogical interventions relies on Randomized Controlled Trials (RCTs), following strict procedures of objectivity, replicability, and statistical analysis. While such a research design is considered as ‘gold standard’, the superiority of RCT procedures has been questioned (see for example the special issue of this journal 2016 issue 39). The limited question of What Works? in the experimental design of RCTs can successfully be complemented with a combination of research methods to address the questions of Why?, How? and In What Contexts? (Hanley, Chambers, and Haslam 2016).

A strict RCT design requires subscription to standardized procedures such as hypothesis testing, reliable and valid outcome measures, the use of appropriate control groups, and adherence to...
detailed intervention protocols (Simons et al. 2016). But fundamental aspects of intervention design, ethical considerations, access to the field, acceptance among participants, and the influence of context risks being overshadowed by the above compulsory measures of a RCT study. For such vital and conclusive knowledge, which is often left undocumented, to come to the fore of the discussion, the publication of pilot studies provides essential opportunities.

**Aim**

The aim of this article is to discuss what a mixed methods research approach, focusing on pedagogical intervention, may provide for the understanding of intervention methodology based on the experiences from a pilot study using two digital learning games. The objectives are to (1) illustrate how a combination of data provide an understanding of how and to what extent the intervention components are functional in the pedagogical setting, (2) to understand how the digital resources and the two digital games afford meaning-making and engagement in the preschool context.

**Background**

Preschool plays an important role in Swedish society. It is not mandatory, but it is tax-financed, and about 80% of children aged 1–6 attend preschool from about 9 am–5 pm five days a week. Groups are often mixed with 1–3-year- and 4–6-year-groups. The national curriculum (Skolverket 2016) emphasizes on a combination of play and learning, care and the fostering of democratic values. Children are seen as competent and active agents in their own learning. They are often taught in groups of 10–20 children with a focus on collective processes along with a strong tendency on following and documenting children’s own interests. In recent years, digital learning tablets have appeared as a new teaching resource, which are used in creative and explorative ways. This coincides with new national policies on the use of Information and Communication Technology (ICT) in school and preschool (Utbildningsdepartementet 2017) and new evidence-based pedagogical methods need to be developed, which can profit from new technologies while staying true to dominating preschool ideology.

A growing body of digital programme development and research has fuelled hope for use of ICT in pedagogical practices. Vast numbers of applications have been developed and promoted as learning-games, brain-games, and cognitive behavioural-applications with promises of enhancing learning, development, and the maintenance of specific skills (Simons et al. 2016). Digital tablets have shown specific potential for preschoolers, for whom the intuitive and symbol-based digital interface is easy to use. Children’s skills are thereby augmented by means of the digital tablet’s affordances (Kjällander 2016). Digital learning devices provide new interactional resources for learning in terms of scaffolding (Haake et al. 2015), peer learning, and creative manipulation (Kjällander and Moinian 2014).

Adaptive and interactive digital applications, in particular, allow individualized learning. Children are given support and challenge for individual needs, without an extensive effort from educators (Ginsburg, Jamalian, and Creighan 2013). Such learning games can also support formative learning processes (Kotler 2011; Husain, Gulz, and Haake 2015) in relation to predetermined learning goals. Other studies show that specific computerized training of cognitive skills, e.g. visuo-spatial working memory, improves these skills (Thorell et al. 2009), and that digital software programmes may contribute to the development of early math skills (Husain, Gulz, and Haake 2015).

Until now, a smaller number of pedagogical intervention studies on mathematics in the digital interface in preschools have been undertaken. Findings indicate the potential of such interventions studies. For instance, Presser, Vahey, and Dominguez (2015) found in an RCT, that teachers successfully integrated and comfortably implemented mathematics programme activities into their current everyday practices. Another RCT study focusing on mathematics (Llorente et al. 2015), in which teachers and preschool children used various technology platforms, including tablet computers, found that these kinds of transmedia resources can enhance math teaching and learning among preschool children. The study indicates that a thoughtful integration of well-designed digital resources, together
with adequate support systems for teachers, can influence both the children’s learning outcomes as well as the teachers’ qualifications in a positive manner. As long as the teachers have adequate mathematical knowledge and pedagogical experience needed to support children’s learning with digital resources, children are able to make use of the learning opportunities available through engagement with the digital media (Llorente et al. 2015). Research also suggests that, when it comes to the structure of their internal image configurations (Goodwin 2008), interactive digital tools support the cognitive apparatus of preschoolers taking part in an intervention (compared to a control group). The research results from a controlled study (Clements and Sarama 2011) of the implementation of a preschool mathematics programme based on research-based software compared to print curricula, indicates that a focused early mathematical intervention can help preschool children develop a foundation of informal knowledge in mathematics. Digital resources can provide unique learning opportunities for preschoolers, and multimedia tools afford possibilities to engage in advanced mathematical ideas, exceeding curriculum obligations and present teaching practices (Goodwin 2008).

Nevertheless, most of the digital learning games have not been scientifically investigated and the actual benefits are questionable (Simons et al. 2016). There is a lack of knowledge regarding which digital features have the best potential in terms of learning. Another study also shows that the use of ICT in preschool settings is dependent on teachers’ attitudes and self-conceived competence (Kercchaert, Vanderlinde, and van Braak 2015). The need for evidence-based practice motivated us to design a large-scale RCT intervention study – where the effect of two learning games on children’s selective attention, executive functions, language, early math skills, and communication was investigated as one of two interventions in the pilot.

To investigate whether there were any measurable outcomes of a Digital Individual Learning (DIL) intervention, it was necessary to make sure that the intervention could be implemented with fidelity, e.g. in the way the investigators intended it to and by following a standardized protocol (Hoffmann et al. 2014; Dennis 2016). This meant that when designing the intervention, the questions of why, how, and under what conditions needed to be addressed. How can a DIL intervention be implemented in a preschool environment? Would it be possible to design the intervention as a 6-week, 1 h per day, 5 days per week activity that would engage children enough to implement it with fidelity? Would the two chosen learning games be functional in the preschool context? How would this be received by teachers and, not the least, by children? How can digital games afford strong engagement and meaning making? What is required from teachers supporting the intervention? What would be the role of the researcher during the intervention? These were some of the main questions that guided the pilot intervention study that was undertaken as part of the large scale and multidisciplinary RCT. Fidelity to the intervention is a key mechanism in intervention research, which requires that the intervention is carefully designed and introduced. To capture the fine-grained qualitative aspects of how well the intervention could be implemented and integrated in the pre-existing dynamic preschool system, a pilot study was undertaken to try out the research design.

The pilot study
To understand how implementation of the potential DIL-intervention in the pilot would fit into the preschool context, a multi-methodological approach was applied. The approach aimed to illuminate the relational dynamics (Mascolo and Fischer 2015) set in motion through the interaction between the digital device, the two learning games, the individual children, teachers, and the social-material context; i.e. the extended digital interface. The main method used was participant observations with video camera, field notes complemented by focus group discussions with teachers and children, and digital game logs. The project follows the ethical guidelines for research with human beings (www.vr.se). Before the pilot was undertaken, the project was granted ethical clearance by the regional Ethics Committee at the Karolinska Institute in Stockholm (www.epn.se/Stockholm/). Attention is given children’s participation and sensitivity to informed consent as a continuous process.
**Presentation of intervention**

The pilot study consisted of a 7-week intervention with a focus on digital individual learning in mathematics. Two digital games: Cogmed JM and Magical Garden were selected as they, in different ways, were expected to contribute to changes in the outcome measures. Both have been the study objects of earlier research projects. As illustrated in model 1, the theory of change (Shonkoff and Levitt 2010) was used to implement and analyse the intervention. The physical and sociocultural context framing the intervention was an ordinary Swedish preschool unit (E). Coregulation and intersubjectivity (D) can here be illustrated in how children’s and teachers’ actions are attuned to each other and to surrounding elements. The theory of change presupposes repeated bi-directional exchange, in terms of co-activated action between the individual child and a digital learning tablet containing two separate digital learning games. This includes material affordances in terms of technical functions e.g. network and games (B), a multimodal perspective on children’s interaction, meaning making and play with digital games, an embodied understanding of acting, feeling and thinking involving processes on neural, cognitive and behavioural levels including the function of language (A) as well as teachers’ support and scaffolding (C) of the co-activated person-environment systems of each individual child (Mascolo and Fischer 2015; Zelazo 2015) (Figure 1).

**The two digital games**

Magical Garden (MG) is developed by researchers at Lund and Linköping Universities, Sweden, in collaboration with Stanford University, USA, and can be described as a digital early math game for preschoolers aged 4–6 (Haake et al. 2015). The general goals and objectives, as defined by the game developers of MG, is to enhance specific skills in terms of children’s number sense and early math, such as numbers, order, addition and subtraction. The programme is theoretically inspired by a [Figure 1. Model of theory of change in the intervention.](#)
Vygotskian tradition (Vygotsky 1978), and gradually introduces levels of increasing difficulty from simple counting to addition and subtraction, and adapts to the child’s individual learning pace and level. It is based on a learning-by-teaching paradigm which means that the child is encouraged to interact with a unique so-called ‘teachable agent’ (Blair et al. 2007), represented in the game as three different animals. ‘A teachable agent (TA) is an instructional technology that capitalizes on the organizing metaphor of teaching another, in this case, a computer agent’ (Chin, Dohmen, and Schwartz 2013, 1). The TA can be taught math by the preschool child (Haake et al. 2015) and provides affordances for the child to be actively and emotionally engaged in the learning process. The basic rules are operationalized in six scenarios/worlds where the child practices mathematics together with the TA.

The storyline, or representation, that undergirds the game is of great importance in MG, which is emotionally and humoristic designed with different characters in need of help. There is, for example, a lost baby bird and a hungry chameleon. It also affords emotional engagement, which motivates the child to teach his/her TA math, and as an effect, develop early math skills. This kind of interaction between users and characters in the digital interface is uncommon among play-and learn apps on the market. MG is so far a beta version and will not be commercialized – the intention is to provide the game to preschoolers during their last year in preschool to prevent mathematical inequalities among children before they start school. The theoretical base for MG in terms of individual adaptation, inclusion and scaffolding is in line with general Swedish pedagogical preschool values (Haake et al. 2015; Skolverket 2016).

Cogmed is designed by Karolinska Institute, Sweden, to train working memory for preschool children aged 4–6. The programme is theoretically based in a neuro-cognitive research tradition. It requires participation for about 10–15 min/day for about 5 weeks. The exercises are individually adjusted and increase gradually in difficulty. The Cogmed game design is associated with an amusement park, presenting six carousel-like activities. However, it is not based on a storyline and does not involving human-like characters to identify and interact with. By watching, memorizing, and clicking at objects in a special order, children are expected to train their working memory. The game has been developed in collaboration with research for almost two decades (Söderqvist and Nutley 2016), and there is substantial research from RCT studies showing the effect of the programme on working memory (Thorell et al. 2009). Cogmed is sold by Pearson, and they provide a 4-hour training for coaches. Cogmed has primarily been used in special education, and the recommendation is that a Cogmed coach guides each child who follows a training. To obtain the best effect, the training should target the threshold of working memory, requiring the child to work at the highest capacity. The role of the coach is important, as the activity is often experienced as exhausting, in order to make the trainee push him/herself towards the limit (Cogmed 2011).

**The setting/room, plan, and preparations**

The DIL-intervention was designed for learning of the specific outcomes early math skills and executive functions, based on previous research with Cogmed and MG as well as the multi-disciplinary research teams’ combined experiences and agendas. The intervention was designed to take place during a 6 week-period (but was prolonged to 7 weeks) in one unit in one preschool in Sweden. This specific unit had 42 children aged 3–6, out of which 17 children were listed to participate in the activity, based on informed consent from the parents.

Two weeks before the intervention, a brief training was held with all teachers at the unit with the intent to facilitate a smooth dynamic fit between the intervention and the existing institutional preschool system. Earlier research (see for example Blair et al. 2007) indicates that mathematical learning can be promoted by using digital tablet-based games in preschool. The training focused on the two learning games MG and Cogmed, the technical handling of the digital tablets, and mixed brief theoretical and practical information with hands-on activities. The idea was that all the teachers would be involved in the implementation of the intervention, and that they would organize how to integrate it into the daily routines in collaboration with the researchers.
The intervention was planned to take place 4–5 times per week for 30–45 min, and the group would be divided in two with 8–9 children in each group assisted by one teacher. A special room was allocated for the activity, furnished with a couple of smaller tables and chairs and an internet connection. The digital games were played on 10 digital tablets provided by the researchers, making it possible for half of the group to play at the same time. In line with the intervention’s theory of change (Shonkoff and Levitt 2010) it was assumed that the actual interaction between the individual child and the digital game would be a precondition for improvement in the outcome measures. For this reason, headphones were provided to each child in order to focus the children’s attention and prevent distractions.

**Ethnographic data production**

One mode of data collection is insufficient when richness of data is of priority (Falloon 2016; Nicholas 2016). To document the intervention, the researchers conducted multiple participant observations. This included direct observations, informal interviews by asking questions to teachers and children and, as main tool for data production, filming of the activity with portable video cameras. We chose the term ‘production’ aligned May’s (2011) statement that data is produced, not collected, as there is no such thing as ‘natural data’ (Blikstad-Balas 2016, 4). In the multimodal data production, the researchers were also equipped with digital tablets to be able to take field notes before, during, and after intervention hour.

**Video documentation, focus groups, and field notes**

Video ethnography makes possible documentation of the educational setting with visual, action-concentrated, and lingual modes expressing different kinds of information that can be interpreted in many ways (Kress and van Leeuwen 1996). The strategy was to document as much as possible during the intervention with main focus on the coregulated actions in the (a) interface between individual child and the digital tablet, (b) interaction between child and pedagogue, (c) interaction child to child and digital tablet, and (d) the whole group interaction.

During and after the intervention group presentations, focus groups with teachers and with children (Krueger and Casey 2009) were held in order to gather the opinions of the participants. The aim was to study how they made meaning of their experiences and involvement in the DIL-intervention. The focus groups were led by researchers who acted as moderators, and a permissive environment was created where non-judgmental discussions were encouraged, not aiming at consensus. The focus groups were audio recorded and thereafter transcribed. Field notes (Jordan and Henderson 1995) that were written at the researchers’ tablets and in notebooks served more as background material, than as empirical data.

**Individual logs in the two digital games**

Falloon (2016) means that new digital tools offer potentials to provide authentic as well as detailed empirical material revealing unique insights into how children interact with digital tablets across spaces and places. Both Cogmed and MG have game logs connected to the programmes registering the interaction enacted by the child playing the game. These logs were useful for monitoring that the child played according to the guidelines to obtain intervention fidelity. The individual game logs are protected by a password that the player enters in order to get access to the personal game trajectory. The benchmark was set at a minimum of 30 min of active playing at each occasion. Data from the digital game logs provide representations of the individual child’s actions in terms of how much time each child has spent interacting with the digital device, as well as what level the child has reached in terms of early math skills and working memory.
Multiple analytical approaches

To illustrate how the combination of video ethnographic methodology, focus groups, and digital game logs contributes knowledge in addition to what can be captured by conventional intervention study procedures, we will present the main findings of the pilot study. But first, a note regarding the analysis: to understand the strengths and challenges of the DIL-intervention, a dynamic systems perspective based on the principle of regulatory processes is suggested (Overton 2013). Strengths are in this context understood in terms of processes that favour repeated and sustained co-regulated action between the individual child and the digital device, so that a dynamic fit is continuously maintained. Challenges, on the other hand, are represented as what we here call dynamic un-fits, meaning that they do not contribute to the goal of strong enough dosage concerning the individual participant’s (teachers and children) actions as well as the functioning of the digital device.

Jewitt’s ‘The Routledge Handbook of Multimodal Analysis’ (2009) guided the analysis of the empirical material, and multimodal transcriptions have been made to reduce versions of observed reality (Flewitt et al. 2009). What is transcribed determines what can be analysed (Jordan and Henderson 1995), and here the focus is on didactic design by means of meaning making as expressed in different modes. The analysis is carried out with multimodal theoretical tools, inspired from a design theoretical perspective (Selander and Kress 2010) on learning by means of teachers’/digital games’ didactic design in the pedagogical setting and the children and teachers’ meaning making in the digital interface. An important notion in this perspective is affordance (Kress and van Leeuwen 1996), which can be explained as the semiotic potential/limitation for representation in a mode. According to Kress (2010), a digital resource, such as a tablet, bestows both hardware and software affordances. What the child recognizes as an affordance depends on the child’s needs, interests, and the specific situation at hand. A multimodal analysis of structural factors and design elements for strong engagement in the digital interface was carried out at first, to identify the games’ affordances for meaning making and strong engagement. Here we assume that strong engagement indicates that children make meaning, and learn, while playing the game. Using six principles ‘that distinguish a really good game from a poor or mediocre one’ (Prensky 2001, 11), a multimodal analysis of the two different games has been carried out by analysing (1) The basic rules; (2) The goals and objectives; (3) The outcomes and/or how feedback is provided; (4) The challenges, conflicts, or competitions; (5) How users interact with the games; and (6) The story or representation that undergirds the games. Different modes (Kress 2010), such as pace, animation, mimic and gesture, colours, symbols and form, sound and music, and speech and voice are analysed in the games. The game logs provided additional data regarding the actual time each child spent interacting with the two games. The focus groups were analysed using content analysis and add additional understandings of the teachers meaning making, interests, and attitudes with regards to the details of the intervention. In addition, field notes were taken during the whole intervention.

The research questions addressed in this paper focus on how a multi method approach can assist in implementing a digital individual intervention with fidelity and compliance. In line with the theoretical perspective, meaning-making is key in understanding to what extent the intervention can unfold as a dynamic system towards the goals of individually enhanced cognitive and math skills.

Multimodal analysis of a multi methods empirical material

Dynamic fits and unfits

From the first day of the intervention, one of two researchers were present at the preschool every day, following the intervention. Despite the initial intention that all teachers who had attended the training would be involved in the intervention, only two out of six teachers were active in the intervention during the first week. Thereafter, only one teacher was involved. The reason for this teacher to persist with the games was that she thought digital resources in education is interesting and fun. We
interpret this as her deciding to take responsibility since she had the digital competence to do so. To support that teacher, we found ourselves directly involved in the activity, interacting with individual children about the digital tablets, passwords, and the content of the games. It was obvious that the interests and meaning making of the teachers, in combination with technical challenges and other ongoing agendas within the dynamic preschool system, contributed to problematic un-fits in the transforming dynamic intervention system. This posed a considerable challenge to intervention adherence and fidelity. In the following section we will describe the major constraints in terms of unfits, to exemplify how the pilot study contributed to the re-design of the RCT-intervention implemented in 29 preschools the following year.

Fits and unfits in the physical preschool setting

An early challenge to the smooth unfolding of the dynamic intervention system was technical, as the network did not support the use of nine digital tablets simultaneously. During the first session, the programmes did not function as intended. The children got stuck in the middle of the game or did not even get started due to internet network failure, disturbing the coregulatory processes and causing distraction from the intended activity among both children and teachers. The network worked fine with about five tablets, but as soon as the game was opened in more tablets, the network crashed. This resulted in waiting children, who eventually became restless, irritated, and not so eager to play the next day. Therefore, it was necessary to divide the group into smaller groups. This in turn disrupted the original plan that had been made together with the teachers and created somewhat confusing first weeks, which resulted in a prolonged intervention. After about one week, another access point was installed so that we could have full groups as originally planned. Unfortunately, at this point, some of the children and teachers had already lost their motivation and declined further participation.

The participant observations and video recorded data from the following weeks document how the children often sat three and three around a low table on low chairs, providing smooth, embodied, and dynamically well-fit designs for learning. Others chose to sit or lie on the big round carpet, profiting from the adaptable affordances of the digital tablet. Physical interaction with the digital interface was by means of a touch screen and headphones. We quickly discovered that the headphones were too large and too warm.

Do I have to wear the headphones? was an often-posed question. Most children chose not to use them at all which contributed to more child-to-child interaction, creating a problematic unfit to the intended individual focus of the intervention.

Fits and unfits in game design

It gradually became evident that the different affordances provided by the two games produced considerably different effects in terms of fits and unfits in the dynamic preschool system. One example is how, in Cogmed, the representation of the figures in different carousels in the amusement park initially attracted most children, most likely due to the aesthetic design. However, the participant observations and multimodal analysis of the video data clearly shows how the children had difficulties making meaning of the content, resulting in them gradually losing interest or becoming frustrated. The children would express this by saying ‘I don’t want to play!’ In MG, the multimodal dialogue between all characters is advanced and turns even more advanced in progression, contributing to high quality coregulated action. There is a focus on individual adaption with inclusion and formative learning, operationalized by direct, rich, and constructive feedback. A significant feature of the children’s strong engagement with the game (Prensky 2001) was by means of the TA. The TA gave the children individual support and challenged them without effort from educators (Ginsburg, Jamalian, and Creighan 2013), thereby supporting formative learning processes (Kotler 2011, 2013; Husain, Gulz, and Haake 2015) and acting as a strong motivator (Chin, Dohmen, and Schwartz 2013).
Each child was challenged by pedagogical assignments at her/his individual level. None of the children were pointed out as in special needs, nor as being a genius. ‘We are at the same level!’ was something children said quite often, even though one child could be practicing the numbers of 1–4 while the other was practicing 5–9. In Cogmed, interactions were clear with a narrative voice instructing the child; however, these children did not appreciate the written instructions as affordances, since they did not read letters. Feedback was provided in a multimodal manner with sounds, mimics, and movement to indicate whether the child clicked on the objects in the right or wrong order. However, the motivational affordances regarding why these objects should be clicked on were lacking.

Another example is how the games’ challenges (conflicts or competitions) were designed. The challenge or goal of MG, appreciated by the children, were to help the TA and the different characters in the game worlds, as well as to make the plants grow. In Cogmed, the goal was to receive many stars and new fish. Cogmed was competitive by means of levels of difficulty, presented on the screen – which can be said to produce an unfit in relation to the preschool ideology. Children were often heard comparing the number of stars they had gained (presented in the top of the screen), and teachers could be heard trying to prevent the comparison of stars. MG, on the other hand, has explicitly been developed to deter competition between children. The idea of inclusion and the importance of self-confidence in learning fits well with Swedish preschool ideology (Skolverket 2016). Furthermore, the design for learning in MG does not present a clear competitive aim concerning mathematical competence, in order to avoid that children struggling with early math start defining themselves as non-capable in it already at this young age. Instead, children are awarded with the same amount of water drops regardless of how well they manage the tasks. Discussions that gradually formed during the study, indicate that children often did not realize that they were engaged in different levels of difficulty in MG. However, both MG and Cogmed afforded various opportunities for interpretations and manipulations, and the video-recorded interaction illustrates how children were comparing how flourishing their gardens were in MG. Some children preferred not to compete and instead made their gardens neat and tidy. The same engagement occurred in Cogmed, where children spent time admiring the fish tanks and ignoring the levels of difficulty (Figures 2 and 3).

**Fits and unfits with preschool ideology**

The content analysis of the focus group discussions about teachers’ meaning making of the intervention provides understandings of how unfits between the content and enactment of the intervention and the institutional preschool culture contributes to challenges to the functionality of the intervention. As reported in the focus group discussions, there was doubt among teachers regarding the ethical and educational values of the DIL intervention. Cogmed was understood as representing a teaching and training agenda, much contested within the dominant institutional framing of the preschool. Critique was also put forwards with regards to the individual focus of the intervention as well as the teacher-directed activities, as opposed to the ideal of following the child’s interests.

Teacher 1: Well, it’s a thought: what hit me about the project, is that a child can choose, they choose the social with friends, instead of sitting with an iPad, and I must say that it is a little gratifying. We have had some problems with motivating children to leave the activity and play (digital tablet). And what it depends on … They do certainly play (digital tablet) at home. But, it can also be because they are in this environment and they are used to being together and we do most things collective in preschool.

Teacher 2: But our activities also affects. When we came to bring the children (to DIL) we had simultaneously begun some other activity and it was hard to leave what we had already started. They did not want to leave the activity that we had started. I tried to bring them in before they had begun the activity instead.

Most teachers at this unit are keen on the collective processes and on helping each other, reluctant to initiating activities where children work and learn individually. The response by teacher 2 above highlights an unfit in how teacher ideology has an impact on what is made possible –
some of the teachers do not want children to spend more time than they already do at home in front of a screen. In this case, the fact that some of the teachers organized other (sometimes more attractive) activities at the same time as the intervention was about to take place threatened the children’s motivation to participate in playing the digital games.

**Fits and unfits with children’s meaning making**

An analysis of the digital log data shows a widespread distribution in terms of child-device interaction time, and the participant observations confirm that some children engaged considerably more with the games than others, posing a threat to the intervention fidelity in terms of dosage. The children’s
testimonies in their focus groups differ. Most of them, however, enjoyed MG but expressed that Cogmed was hard work.

Researcher So, all of you thought Cogmed was fun? And the Magical Garden?
Children YES! (laughter)
Researcher Was there something with the games that was not fun?
Child 1 The hairballs (in Cogmed) were boring!
Child 2 Both were fun, that’s what I think.
Child 3 But I thought all games were boring.

‘I don’t want to play!’ was commonly heard from many children while playing Cogmed. A considerable number of children were not attracted to the activity, indicating in different modes that they did not want to play. This reveals an unfit. The children got bored, had problems focusing on the games, and thought it was hard work. Herein lies a conflict: playing in this study was framed by a preschool context with norms and curriculum of a lust- and interest driven activity (Skolverket 2016), which created a paradox to the requirement in Cogmed of a supporting and persuasive coach role. This position by the children also created a delicate ethical research dilemma. According to the rule of consent, it was by no means an option for neither the researchers nor the teachers to force any child to participate, and no such situation occurred. However, it was evident that the statement, ‘I don’t want to play!’ could have different meanings and be interpreted in several ways. In many cases, as the multimodal analysis show, the child would state this following many missed trials in the game because the child did not understand the instructions. With the support from one of the teachers or researchers, the child would quickly get back on track and happily continue to play for the rest of the session. It was also evident that this resistance was partly related to the digital interface of the game. There was a clear difference between Cogmed and MG in this respect with MG providing more affordances for coregulated action and positive meaning making in terms of identity formation than Cogmed.

Concluding discussion

In the beginning of this article, we asked how a digital individual intervention can be designed to work with fidelity, alluding both to the research methodological context as well as the preschool practice context. We illustrate the potential of a multi-methods approach in the early stage of designing a pedagogical RCT-study focusing math in the digital interface, through the example of this pilot study and the theory of change (Shonkoff and Levitt 2010). By foregrounding meaning making and a multi-method approach, we argue that the quality of a pilot study, of this sort, depends on the methodological capacity to capture the complexity of the dynamic system (Overton 2013), into which the intervention is introduced. It is further suggested that an analysis of the dynamic system can be taken as point of departure in the design of a functional intervention, following a specified theory of change along with specific materials to which the participants are able to adhere. We have interfered, not only by implementing the intervention, but also with our physical presence in the observation setting as we cannot escape the social world to study it (Hammersley and Atkinson 2007). However, the ethical demands on informed consent in communication with children and teachers is more important than being able to delimit observation effects (Nicholas 2016) and this study shows that the material can be nuanced by using different methods. How well the games afford children to make meaning and engage strongly in the digital interface was crucial for intervention implementation and is illustrated by different empirical material and in different modes. We argue that the dynamic fit between (i) the content, goals and functioning of the two games; (ii) the ideological underpinnings of the preschool pedagogy; and (iii) individual children and teacher’s interests and meaning making is crucial for the intervention to be functional. This, in turn, requires a multi-methods approach to describe and analyse. The information obtained through the focus group made us understand the teachers’ reluctance against training working memory with the digital tablet. The game logs held information about how much time each child spent interacting with the game.
These different empirical materials also make clear that the topic of mathematics fits more obviously into the preschool curriculum (Skolverket 2016) in terms of early math, whereas working memory as a general (and more abstract) skill more readily is associated with a neuro-cognitive discourse and potentially not as easy for teachers to make meaning of. The resistance we experienced among the teachers is also partly explained by the hegemonic preschool discourse which argues that preschool practice should focus collective processes as well as a strong tendency on following children’s own interests (Skolverket 2016), which means that it is controversial to encourage children to play games individually. It can also be a question of, not only attitude, but a lack of self-conceived competence, as research by Kerckaert, Vanderlinde, and van Braak (2015) reveals. The conclusion of the analysis supports the finding that unless children’s and preschool teachers’ meaning making of the unfolding actions in the digital interface makes them engage in the activity and dynamically fits within the institutional preschool system, the intervention will not be functional. This, in turn, will be a threat to intervention adherence and fidelity (Hoffmann et al. 2014). We hereby argue for the use of pilot studies before a large-scale intervention implementation, not only because of above reasons, but also with the aim of preventing waste of time and finances.

One question remains: are we ready for individual digital learning in the preschool? Earlier math-intervention studies in the digital interface show that it is possible (Llorente et al. 2015; Presser, Vahey, and Dominguez 2015), as well as desired, if one shall believe Clements and Sarama (2011) and Goodwin (2008). The latter study indicates that such interventions can help young children develop informal knowledge in mathematics, and that digital tools can afford children possibilities to engage in advanced mathematical ideas (Goodwin 2008). Our study indicates that we are ready, given the quality of digital individual learning. The methodological redesign of the intervention should focus exclusively on MG. However, MG requires individual teacher initiated scaffolding when the digital game fails to adjust to the child’s individual level, challenging the child’s motivation and self-regulation – an aspect that needs to be improved in the main study. Since the DIL-intervention was supposed to train working memory, alternatives for this are being explored with inspiration from the Brain Development Lab at Oregon University.5 There is furthermore a need for improved training of teachers to enhance their self-conceived digital competence in order to integrate a digital intervention in the overall organization, as well as technical assistance to guarantee network capacity.

Notes
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2. Educational Technology Group.
3. AAA-lab.
4. Klingberg Lab.
5. https://bdl.uoregon.edu/.

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