Title

A mixed-methods feasibility study of a gamified therapy prescription app for children with neurodisability

Authors

Rowan W Johnson [1,2], Becky K White [3,4], Daniel F Gucciardi [2,5], Noula Gibson [2,6], and Sian A Williams [2,7]

Affiliations

[1] Therapy Services, Ability WA, Perth, Australia
[2] Curtin School of Allied Health, Curtin University, Perth, Australia
[3] Curtin School of Population Health, Curtin University, Perth, Australia
[4] Reach Health Promotion Innovations, Perth, Australia
[5] Curtin enAble Institute, Faculty of Health Sciences, Curtin University, Perth, Australia
[6] Department of Physiotherapy, Perth Children's Hospital, Perth, Australia
[7] Liggins Institute, The University of Auckland, Auckland, New Zealand

Corresponding Author

Rowan Johnson
rowan.johnson@health.wa.gov.au

Johnson, R.W., White, B.K., Gucciardi, D.F., Gibson, N., & Williams, S.A. (in press). A mixed-methods feasibility study of a gamified therapy prescription app for children with neurodisability. *Physical & Occupational Therapy in Pediatrics*. doi: 10.1080/01942638.2023.2263576

Abstract

Aim: Determine the feasibility of a gamified therapy (occupational therapy, physiotherapy, speech pathology) prescription app developed for children with neurodisability for delivering school and home therapy programs (the Zingo app).

Method: A mixed-methods feasibility study was conducted with children (and their parents, therapists, and teachers) with neurodisability (n=8, female= 5) who were prescribed a 4-week individualized therapy program by their usual treating therapist using Zingo. Primary outcome measures were program adherence, engagement, app quality, and user experience, collected with quantitative and qualitative methods.

Results: Mean adherence to the program was 58.0% (SD 27.2). Our combined Engagement Index (EI) score was 74.4% (SD 11.7). App quality measured using Mobile Application Rating Scale-User version was 4.6/5 (SD 0.7, n=6) for parents, 4.6/5 (SD 0.5, n=5) for teachers, and 4.4/5 (SD 0.6, n=6) for therapists. Thematic analysis of semi-structured interviews yielded a primary theme of "app as motivator" for therapy.

Conclusions: Adherence findings were affected by COVID-19 outbreak however remain comparable with other studies in this cohort. EI findings compared favorably with other studies. The findings are supportive of the feasibility of Zingo for delivering home and school therapy programs for children with neurodisability and was found to motivate therapy program completion.

Keywords

physiotherapy, physical therapy, occupational therapy, speech pathology, pediatrics, mobile health technology

In children with neurodisability, goal-directed home programs are widespread (Iona Novak & Cusick, 2006; Peplow & Carpenter, 2013) and empirically supported for facilitating therapy activity practice between face-to-face therapy sessions (Iona Novak & Berry, 2014; I. Novak et al., 2020; Sakzewski et al., 2014). Utilizing a collaborative, family-centered model for the provision of home programs is considered best-practice (Iona Novak & Cusick, 2006), yet ensuring there is sufficient adherence to achieve the desired outcomes remains a common challenge in clinical practice (Carmen Lillo-Navarro et al., 2015; Peplow & Carpenter, 2013). The World Health Organization recognises that mobile health (mHealth) technologies have the potential to transform health service delivery (*mHealth: New horizons for health through mobile technologies*, 2011) and may have a role in supporting therapy adherence. However, research indicates that a generic exercise prescription app (Physitrack) will offer little advantage for program adherence for children with neurodisability over conventional paper-based programs (Johnson et al., 2020).

The 'F-words' for child development highlights a well-recognized principle that therapy (physiotherapy, occupational therapy, speech pathology) for children with neurodisability should be a "Fun" and "Functional" experience (Rosenbaum & Gorter, 2011). Recognition of the importance of meaningful play in therapy has garnered attention to the potential of technology-assisted gamification of therapy for children (Dan, 2022). Gamification, defined as the use of gaming elements in a non-gaming context (Deterding et al., 2011), of home and school programs has potential to help make therapy practice engaging and fun for children, and thereby improve program adherence (Johnson et al., 2022; Schoeppe et al., 2017). Key features identified by users to achieve an engaging therapy prescription app for children include using videos with children as models, age-appropriate games, and rewards for activity completion (Johnson et al., 2022). This

research informed the development of a new purpose-driven app, called 'Zingo', designed to deliver home and school therapy programs in a way that is fun and effective in improving adherence for children.

Initial development of the Zingo app involved Intervention Mapping and user-centered design principles by which motivationally-informed behavior change techniques (BCTs) (Deci, 1985) were embedded in the app and visual elements were judiciously selected to be engaging for children (Johnson et al., 2022). As a next step, we sought to evaluate use of Zingo to understand how children with disabilities engage with the app and what changes might be required for clinical and research use. Specifically, we aimed to evaluate the feasibility of Zingo for the provision of school and home therapy programs for children with neurodisability.

Methods

Design

A mixed-methods, single group feasibility study with a convergence triangulation design, was conducted (Creswell & Plano Clark, 2011). Each participating child was provided with a 4-week school therapy program by their treating therapist using Zingo. Study outcomes were selected to inform our understanding of the fidelity, acceptability, and perceived value of the intervention (El-Kotob & Giangregorio, 2018; O'Cathain et al., 2015) to determine the feasibility of using the Zingo app to deliver individualized home and school programs. Primary outcomes were adherence, objective and subjective engagement with technology, app quality, and app experience. Secondary outcome measure was goal attainment. See Table 1 for outcome measurement procedures.

Ethical approval was obtained from the Human Research Ethics Committee, Curtin University, Perth, Western Australia (reference HRE2018-0696). Approval for research to be conducted in primary schools in Western Australia was given by the Department of Education. This study was prospectively registered with Australian New Zealand Clinical Trials Registry (reference ACTRN12619001356156, registered 3 October 2019).

Participants

A convenience sample of children aged 6 to 12 years old with neurodisability (e.g. Cerebral Palsy, Autism Spectrum Disorder, Intellectual Disability) requiring a therapy program and attending mainstream schools (in Perth, Western Australia) were recruited over January to March 2020. To be included participants had to have effective verbal communication (as confirmed by their therapist), access to an Apple iOS device and internet at school. Participants were excluded if they were undergoing any intervention that would adversely affect their capacity to follow a therapy program, including hospital admissions common to children with neurodisability such as orthopedic surgery or respiratory infections, or significant community interventions such as serial casting. We did not consider recent Botulinum Toxin Type-A injections an intervention necessitating exclusion from study, as children should continue normal activities, in most cases. In keeping with a flexible and pragmatic approach to this feasibility study, a total of 10 participants were sought for recruitment with consideration to the breadth of outcome measures to be collected from each participant including semi-structured interviews. Due to the age of the children, feedback was also sought from their parents, therapist, and teachers to understand how the app was viewed in a wider context. Written and informed consent by parents and teachers, and verbal assent from children, was provided for all participants.

Intervention

Zingo is a gamified therapy prescription app with two interfaces for the provision of individualized school and home therapy programs. We have published our user-centered app development process that utilized Intervention Mapping for embedding behavior change techniques into the app design (Johnson et al., 2022). One interface is for a therapist to set an individualized program including therapy activity videos and written instructions. The second interface is a gamified interface where the child can view the activity videos and instructions, perform the activities, provide real-time feedback from the child to the therapist on their experience of performing therapy program, and enjoy therapy completion incentives for a digital pet (See Figure 1). Three levels of gamified incentives, along with a choice of 3 different anime-style digital pets with different incentives for each, were utilized with a view to keep the child engaged with the app: i) the opportunity to give your pet "food", "water", and "love" with each activity completion that fills up health bars and enhances your pet's emotional state; ii) with each activity earning a "star" that fills the "star bar" that leads to an evolution of the pet to stronger versions; and iii) monitoring progress towards weekly activity goals that earns the user "coins" to spend in the "pet shop" to buy digital items for their pets (e.g. collars, pet bowl, pet toy, fantasy pet houses).

A research investigator (RJ) provided participating therapists (occupational therapists, physiotherapists, and speech pathologists) with training and written instructions in the study procedures they needed to follow and in how to use Zingo to set up and monitor a therapy programs. Prior to start of the 4-week therapy program, the child, their parent and their therapist collaboratively set goals to guide the selection of therapy activities. Two school visits were then

conducted by the therapist to demonstrate and trial the therapy activities, determine suitable program parameters, and assist the teacher in accessing Zingo on the classroom iPad. If a classroom iPad was unavailable, the study team provided one. RJ contacted the teacher to ensure there were no technical issues and confirm the program start and finish dates.

The intervention occurred in March to April 2020, coinciding with the advent of the COVID-19 pandemic in Australia. During the 4-week intervention period schools were closed for most students and 7 (of 8) participants were home-schooled by their parents. All 7 participating parents gave permission to continue the therapy program at home, with the support provided by RJ at the transition to ensure access to Zingo. The one other student continued their program at school. Post-intervention questionnaires and interviews were completed in April 2020.

Measures and Analysis

Adherence to therapy

Data demonstrating adherence to the therapy program was collected in real-time within the Zingo app. When a child started an activity a colorful timer screen appeared prompting the child to continue the activity; the time corresponded to the minimum activity time prescribed by the therapist. Children were unable to press the 'finished' button until the timer ran out to ensure integrity of adherence data. The child then confirmed completion of the activity within the app (a button to acknowledge that they didn't finish the activity is also available), and the completion was recorded for adherence. Non-digital strategies employed to check that in-app adherence represented real activity completion included therapist training, and phone calls to teachers and parents before program implementation, to ensure that the child is supervised when using Zingo

both for providing support and to ensure they complete activities. Adherence was calculated as the number of activities completed as a proportion (expressed as %) of those prescribed by the therapist over the 4-week intervention period.

Engagement with Zingo

Engagement with mHealth technology is a multi-dimensional construct (Perski et al., 2017). Perski et al. (2017) defines engagement with digital health interventions as "(1) the extent (e.g. amount, frequency, duration, depth) of usage and (2) a subjective experience characterized by attention, interest and affect." Aspects of this definition were incorporated into our multipronged measurement of engagement by designing an Engagement Index (EI) incorporating app usage data to measure the "extent of usage" across amount, frequency, duration, and depth of usage (Table 2).

The subjective experience of the users was evaluated post-intervention with the User Experience Questionnaire (UEQ) (Schrepp et al., 2017) by interview with the children (with the assistance of their parents). UEQ findings were analysed using UEQ Data Analysis Tool Version 8 to provide descriptive statistics and benchmarking of the results (Schrepp et al., 2017). App usage data and UEQ findings were inputted into an EI developed specifically for Zingo to yield a combined engagement score (Table 2).

App Quality and Experience

Zingo quality was measured with the Mobile Application Rating Scale - User Version (uMARS) by the parents, therapists, and teachers of participating children (Stoyanov et al., 2016). uMARS

was not used with participating children because the reading requirement exceeded that expected of children 6-12 years with neurodisability, and previously had not proved efficacious in this cohort (Johnson et al., 2022).

A purpose-designed Zingo Experience Questionnaire was developed for teachers and parents to complete seeking feedback on i) the child's independence in using Zingo and completing the therapy activities, ii) their experience of using Zingo (including ease of completing therapy activities, their enjoyment as caregiver, practical considerations), and iii) the child's interest in using Zingo at different time points during the trial.

Goal attainment

The Canadian Occupational Performance Measure (COPM), modified for use with children (Cusick et al., 2007; Law et al., 2014), was used to measured attainment. Parents rated their child's goal-activity performance, and their satisfaction with the performance, at the beginning and end of the 4-week intervention period. The mean and standard deviation pre-post change COPM scores are reported. The proportion of participants who achieved a 2-point pre-post change is also reported since this 2-point change is considered a clinically meaningful change for COPM (Law et al., 2014).

Qualitative data collection

Semi-structured interviews were completed by RJ via phone or videocall with the participating children and their parent post intervention. Originally face-to-face interviews were planned but these were altered to phone or videocall interviews to comply with COVID-19 restrictions.

Interviews encompassed the child's experience using the app, and completing the prescribed therapy activities; in particular, to ensure that app usage did reflect real therapy activity completion, both at school and home. Interview questions were designed to provoke perceptions of app usability, acceptability, and engagement; there were also questions designed to evaluate specific app elements in day-to-day use (Supplementary table 1). Audio-recorded data were transcribed and reviewed and coded (using NVivo) by two researchers (BW & RJ) using the guidelines for thematic analysis developed by Braun et al. (2016) to abductively (combination of deductive and inductive (Sparkes & Smith, 2014)) examine participants' responses with regard to themes of acceptability, usability, engagement and fidelity of app-prescribed therapy programs. The two sets of coding were compared for reliability and consistency, with coded data triangulated with the quantitative data to determine app feasibility.

Results

Participants

Fifteen therapists working at Ability WA, a not-for-profit disability service provider, (6 Occupational Therapists, 6 Physiotherapists and 3 Speech Pathologists) identified 23 children meeting the selection criteria for participation in the study within their caseload from which nine consented to participate. One participant withdrew before the 4-week intervention period began due to their parents' change of priorities; 8 completed the study (see Table 3).

Adherence to therapy

The therapists for the 8 participants prescribed a total of 41 therapy activities with a mean of 5.1 (Standard deviation (SD) 1.2) activities per child. These included a broad range of therapy activity

types in keeping with the intension to prescribe individualized programs: body-weight resistance strength exercises (22.0%), gross motor activities (19.5%), stretches (14.6%), standing balance (12.2%), expressive language activities (9.8%), fine motor activities (9.8%), ball skill activities (4.9%), respiratory exercises (4.9%), and walking mobility (2.4%). Adherence data for 7 of the 8 participating children were obtained for the complete 4-week intervention period. Data for the additional participant was only available for the first 3 (of 4) weeks due to therapist error with inputting program duration into Zingo. Overall, mean adherence to the program was 58.0% (SD 27.2%), which includes the partial data for the 8th participant.

COVID-19 affected school attendance and the location that the program was completed. One participant completed the program at school for the whole period, 1 participant was at home the whole period, and the remaining 6 completed their therapy program on Zingo partially whilst attending school (median 2 weeks) and partially at home. Weekly mean adherence was also calculated for time periods of the program undertaken at school [78.3% (SD 23.7%)] and at home [40.4% (SD 38.2%)].

Engagement with Zingo

Subjective engagement with Zingo was measured with the UEQ in 6 participants (2 did not complete UEQ after the researcher and parent decided that the child did not have the capacity to comprehend the questions). UEQ scores varied between +1.7 to +2.5 (on a 6-point scale -3 to +3) on each of the sub-scales of the UEQ (Table 3). These means are in the top 10% range compared to products included in the UEQ benchmark data of software and information technology products

(Figure 2) (Schrepp et al., 2017). The overall subjective EI score (the combined UEQ scale mean) was 83.7% (SD 13.1).

Objective engagement with Zingo assessed using the app usage data from 8 participants that, according to our EI, yielded an objective engagement mean score of 63.5% (SD 17.0). The combined objective and subjective results together result in an overall EI of 74.4% (SD 11.7).

App Quality and Experience

Teachers

App quality findings using uMARS were collected from 5 participating teachers with a mean app objective quality score of 4.6 (SD 0.5; on a 5-point scale). The Zingo Experience Questionnaire findings were that teachers perceived the children understood the app, teachers enjoyed the experience, children were interested in using the app, and motivated to complete therapy activities (Supplementary table 2). The remaining 3 teachers reported that they did not get to use Zingo sufficiently to complete the questionnaire (due to COVID-19 related transition to a home program).

Parents

App quality findings were collected from 6 of the 8 parents of participating children using uMARS, with a mean objective quality score of 4.6 (SD 0.7). Two parents reported they did not use it sufficiently at home to report on their app experience. User experience findings were collected from 7 of the 8 parents with the Zingo Experience Questionnaire. All parents reported that the children understood the app, the parents enjoyed the experience, the children were highly

interested in using the app, and highly motivated to complete therapy activities (Supplementary table 2).

Therapists

Six of the 7 participating therapists (one therapist had 2 children in the study) completed uMARS, with a mean for app quality of 4.4 (SD 0.6) (Supplementary table 2).

Goal attainment

Each parent and child collaboratively specified 1 to 2 goals for the therapy program. The programs provided had a goals mostly in the activity domain of the International Classification of Functioning, Disability and Health (ICF): 2 children had walking mobility goals (1 speed and 1 endurance); 4 children had other locomotor goals (1 jumping, 1 skipping, and 2 hopping); 1 child had expressive language goals (naming with nouns and use of clarity strategies); 1 child had a ball control goal (soccer kicking); and 1 child had a functional balance goal (reduced falls in playground). One child had a fine motor goal (cutting with scissors) however this unable to be included in the COPM scores as the parent reported she did not witness this at home, he only did it at school. There was 1 goal in the participation domain of the ICF: that the child would keep up with her peers on play equipment at school. There was a COPM mean change of +2.2 (SD 2.2) in activity performance and +3.6 (SD 3.1) in performance satisfaction. A clinical meaningful change score occurred in 62% (n=5/8) of participants for performance and 75% (n=6/8) of participants for satisfaction.

Qualitative findings

The analysis of the semi-structured interviews (n=8 parent-child dyads) identified the overarching primary theme of the "App as a motivator" for therapy activities. Seven of the 8 participants identified that they did more therapy practice using Zingo than they would normally do. Two of the parents participating in the interviews stated explicitly that Zingo motivates their child to complete their therapy tasks. One parent spoke of their child's improved engagement in therapy activities; this child reported they did not always enjoy the therapy activities themselves, but they enjoyed them because of the app. One child's report of regular activity completion, with self-monitoring of progress using in-app features, was congruent with the design of Zingo to promote autonomous motivation (Johnson et al., 2022):

> *"Every day I'd look on my stars, I'd choose a stretch and then I'd try to get that many stars for it.*" Child 5

Four secondary themes were identified: Fun, Autonomy, Goal setting and progress, and Identifying with digital pet.

> *"…she seemed to quite enjoy it and look forward to doing it in the morning."*
>
> Parent 5

> *"..it was colourful and it's easy to, kind of easy to find your way around and how to do it by yourself."* Child 5

> *"…so your minimum goal is 80% and you earn coins when you reach the goal."*
>
> Child 1

> *"It was like, oh, let's make [the Zingo pet] happy again and she knew, she knew instinctively what to do. We needed those stars…"* Parent 3

A summary of the primary theme and each sub-theme, with example quotations from participants, is provided in Table 4. None of the participants reported unintended consequences or harms.

Discussion

This study aimed to determine the feasibility of the Zingo app for improving home exercise prescription adherence in children with neurodisability. Both the quantitative testing methods and the semi-structured interviews were supportive of Zingo as a feasible method for delivering home and school therapy programs for children 6-12 years old with neurodisability, and that it can improve adherence and enjoyment of therapy activities.

Reported adherence rates to home therapy programs in children with disability have ranged from 34% up to 99% with adherence reported to be affected by type of exercises and by clearly defined intervention protocols (e.g. Constraint Induced Movement Therapy) (Beckers et al., 2020; C. Lillo-Navarro et al., 2019). In our study, the program implementation was significantly affected by the onset of the COVID-19 pandemic, with three quarters of participants starting the program at school but part-way through having to continue the intervention at home. Some parents reported being unable to continue at home because of the combined responsibilities of working from home, home schooling, and home therapy. Nonetheless, the overall adherence across home and school use reported here was comparable to other studies. The comparable adherence rates achieved using Zingo, despite these complications, supports the premise that Zingo is a feasible method for delivering therapy programs.

Both the semi-structed interviews and questionnaires supported the quality of Zingo, with ratings high in all uMARS domains (engagement, functionality, aesthetics, and information quality). Children, parents, and teachers all reported Zingo to be understandable, enjoyable, and interesting. Importantly, Zingo was considered motivating for children to practice home therapy because they found it fun; it supported their autonomy, goal setting and monitoring goal progress; and the children identified with the 'digital pets' gamification feature.

Our multi-faceted engagement measures combined questionnaire, app usage data, and semi-structured interview data, and Zingo produced strong engagement findings in this feasibility analysis. When considering subjective engagement using the UEQ, benchmarked results were in the top 10% of findings. An acknowledged weakness of UEQ is that it does not distinguish between technology types, with benchmark data coming from a variety of products (e.g. business software, websites); conversely, the authors do anticipate some generalizability of findings, as users may expect engagement innovations to translate across platforms (Schrepp et al., 2017). The UEQ results were supported by qualitative data, with children reporting positive experiences with Zingo, describing how they found the digital pets and other gamification strategies engaging. Our engagement findings, via our combined EI (74%), compares favorably with other studies of child health apps who had EI means of approximately 30% (Taki et al., 2017; White et al., 2012). However, the differences in app design, that these apps were aimed at parents, and the differences in EI algorithm design, mean that direct comparison of EI results may be misleading. Future research measuring engagement- with apps designed for direct use by children rather than parents- may enable more edifying comparisons.

The COVID-19 pandemic had many significant impacts for children with neurodisability, with access to medical and allied health care leading to a decline in children's mobility, physical activity pain, communication, social skills, sleep and behavior (Merrick et al., 2023). The delivery of therapy changed during the pandemic with reduced frequency of services, increased use of telehealth, and a shift towards interventions being delivered by parents (Cacioppo et al., 2021; Merrick et al., 2023). Telehealth for delivery of therapy was significantly challenging for therapists and families, with reduced parental satisfaction; therefore a refining of the use of telehealth and identifying other approaches to support children with disabilities is needed during a health emergency (Merrick et al., 2023). App delivered home and school therapy programs, may provide this support. In-app features such as videos of prescribed activities, and embedded behavior change techniques to improve motivation may alleviate some of the caregiver burden in provision of home therapy. Real-time feedback features can support communication about therapy activities in periods of social isolation. In addition, the use of gamification with technology-supported interventions is an extension of the play-based therapy approaches commonly used by therapists to maintain engagement and maximize gains with conventional therapy intervention (Dan, 2022).

The mixed-methods approach used in this feasibility study draws on qualitative data to inform quantitative findings of adherence, engagement, participant experience, and goal attainment; the thematic analysis of our qualitative findings was essential in gaining a richer understanding of participant experience for interpreting our quantitative findings. Another strength of this study

is that the intervention, Zingo app, was developed with a motivationally-informed, user-centered, iterative design incorporating theory-informed BCTs (Johnson et al., 2022). Evaluation was flexible to the needs and abilities of the children. Weaknesses of this study include the uncontrolled design with a small sample size (n=8). There is potential for bias with unblinded assessment used. The intervention period of 4 weeks was relatively short. Future studies would benefit from tracking adherence for longer and a controlled study design in order to determine whether Zingo is more effective than conventional therapy prescription methods in improving adherence.

Conclusions

This study supports the feasibility of using Zingo to deliver home and school therapy programs for school aged children with neurodisability, although the sample size here does not permit a conclusive outcome. These findings cannot be generalized to other populations including children without disability or adults. Zingo was designed with theory-informed BCTs and significant emphasis on gamification and, notably, participants described how Zingo was fun and motivated them to complete their prescribed therapy program. The Zingo App was identified by parents, therapists, and teachers as a viable means of delivering therapy programs and supporting adherence.

REFERENCES

Beckers, L., Geijen, M. M. E., Kleijnen, J., E, A. A. R., M, L. A. P. S., R, J. E. M. S., & Janssen-Potten, Y. J. M. (2020). Feasibility and effectiveness of home-based therapy programmes for children with cerebral palsy: a systematic review. *BMJ open*, *10*(10), e035454. https://doi.org/10.1136/bmjopen-2019-035454

Braun, V., Clarke, V., & Weate, P. (2016). Using thematic analysis in sport and exercise research. In B. Smith & A. C. Sparkes (Eds.), *Handbook of Qualitative Research in Sport and Exercise* (pp. 191-205). Routledge.

Cacioppo, M., Bouvier, S., Bailly, R., Houx, L., Lempereur, M., Mensah-Gourmel, J., Kandalaft, C., Varengue, R., Chatelin, A., Vagnoni, J., Vuillerot, C., Gautheron, V., Dinomais, M., Dheilly, E., Brochard, S., Pons, C., & Group, E. (2021). Emerging health challenges for children with physical disabilities and their parents during the COVID-19 pandemic: The ECHO French survey. *Ann Phys Rehabil Med*, *64*(3), 101429. https://doi.org/10.1016/j.rehab.2020.08.001

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed. ed.). SAGE Publications.

Cusick, A., Lannin, N. A., & Lowe, K. (2007). Adapting the Canadian Occupational Performance Measure for use in a paediatric clinical trial. *Disability & Rehabilitation, 2007, Vol.29(10), p.761-766*, *29*(10), 761-766. https://doi.org/10.1080/09638280600929201

Dan, B. (2022). Gamification of therapy: the fun factor in rehabilitation. *Dev Med Child Neurol*, *64*(3), 276. https://doi.org/10.1111/dmcn.15126

Deci, E. L. (1985). *Intrinsic motivation and self-determination in human behavior / Edward L. Deci and Richard M. Ryan*. New York : Plenum.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: defining "gamification". *MindTrek '11: Proceedings of the 15th International Academic MindTrek Conference*, 9-15. https://doi.org/10.1145/2181037.2181040

El-Kotob, R., & Giangregorio, L. M. (2018). Pilot and feasibility studies in exercise, physical activity, or rehabilitation research. *Pilot Feasibility Stud*, *4*, 137. https://doi.org/10.1186/s40814-018-0326-0

Johnson, R. W., White, B. K., Gucciardi, D. F., Gibson, N., & Williams, S. A. (2022). Intervention Mapping of a Gamified Therapy Prescription App for Children With Disabilities: User-Centered Design Approach. *JMIR Pediatr Parent*, *5*(3), e34588. https://doi.org/10.2196/34588

Johnson, R. W., Williams, S. A., Gucciardi, D. F., Bear, N., & Gibson, N. (2020). Can an online exercise prescription tool improve adherence to home exercise programmes in children with cerebral palsy and other neurodevelopmental disabilities? A randomised controlled trial. *BMJ Open*, *10*(12), e040108. https://doi.org/10.1136/bmjopen-2020-040108

Law, M., Baptiste, S., Carswell, A., McColl, M. A., Polatajko, H., & Pollock, N. (2014). *Canadian occupational performance measure (COPM)*. Canadian Association of Occupational Therapists (CAOT).

Lillo-Navarro, C., Medina-Mirapeix, F., Escolar-Reina, P., Montilla-Herrador, J., Gomez-Arnaldos, F., & Oliveira-Sousa, S. L. (2015). Parents of children with physical disabilities perceive that characteristics of home exercise programs and physiotherapists' teaching styles influence adherence: a qualitative study. *Journal of Physiotherapy*, *61*(2), 81-86. https://doi.org/10.1016/j.jphys.2015.02.014

Lillo-Navarro, C., Montilla-Herrador, J., Escolar-Reina, P., Oliveira-Sousa, S. L., Garcia-Vidal, J. A., & Medina-Mirapeix, F. (2019). Factors Associated with Parents' Adherence to Different Types of Exercises in Home Programs for Children with Disabilities. *J Clin Med*, *8*(4). https://doi.org/10.3390/jcm8040456

Merrick, H., Driver, H., Main, C., Kenny, R. P. W., Richmond, C., Allard, A., Bola, K., Morris, C., Parr, J. R., Pearson, F., Pennington, L., & Resetting Services, T. (2023). Impacts of health care service changes implemented due to COVID-19 on children and young people with long-term disability: A mapping review. *Dev Med Child Neurol*, *65*(7), 885-899. https://doi.org/10.1111/dmcn.15503

mHealth: New horizons for health through mobile technologies. (2011). (Vol. 3). World Health Organisation. https://www.who.int/goe/publications/goe_mhealth_web.pdf

Novak, I., & Berry, J. (2014). Home program intervention effectiveness evidence. *Physical & Occupational Therapy In Pediatrics*, *34*(4), 384-389.

Novak, I., & Cusick, A. (2006). Home programmes in paediatric occupational therapy for children with cerebral palsy: Where to start? *Australian Occupational Therapy Journal*, *53*(4), 251-264. https://doi.org/10.1111/j.1440-1630.2006.00577.x

Novak, I., Morgan, C., Fahey, M., Finch-Edmondson, M., Galea, C., Hines, A., Langdon, K., Namara, M. M., Paton, M. C., Popat, H., Shore, B., Khamis, A., Stanton, E., Finemore, O. P., Tricks, A., Te Velde, A., Dark, L., Morton, N., & Badawi, N. (2020). State of the Evidence Traffic Lights 2019: Systematic Review of Interventions for Preventing and Treating Children with Cerebral Palsy. *Curr Neurol Neurosci Rep*, *20*(2), 3. https://doi.org/10.1007/s11910-020-1022-z

O'Cathain, A., Hoddinott, P., Lewin, S., Thomas, K. J., Young, B., Adamson, J., Jansen, Y. J., Mills, N., Moore, G., & Donovan, J. L. (2015). Maximising the impact of qualitative research in feasibility studies for randomised controlled trials: guidance for researchers. *Pilot Feasibility Stud*, *1*, 32. https://doi.org/10.1186/s40814-015-0026-y

Peplow, U. C., & Carpenter, C. (2013). Perceptions of Parents of Children with Cerebral Palsy About the Relevance of, and Adherence to, Exercise Programs: A Qualitative Study. *Physical & Occupational Therapy In Pediatrics*, *33*(3), 285-299. https://doi.org/10.3109/01942638.2013.773954

Perski, O., Blandford, A., West, R., & Michie, S. (2017). Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. *Transl Behav Med*, *7*(2), 254-267. https://doi.org/10.1007/s13142-016-0453-1

Rosenbaum, P., & Gorter, J. W. (2011). The 'F-words' in childhood disability: I swear this is how we should think! *Child Care Health Dev*, *38*(4), 457-463. https://doi.org/10.1111/j.1365-2214.2011.01338.x

Sakzewski, L., Ziviani, J., & Boyd, R. N. (2014). Efficacy of upper limb therapies for unilateral cerebral palsy: a meta-analysis. *Pediatrics*, *133*(1), e175. https://doi.org/10.1542/peds.2013-0675

Schoeppe, S., Alley, S., Rebar, A. L., Hayman, M., Bray, N. A., Van Lippevelde, W., Gnam, J. P., Bachert, P., Direito, A., & Vandelanotte, C. (2017). Apps to improve diet, physical activity and sedentary behaviour in children and adolescents: A review of quality, features and behaviour change techniques [Article]. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), Article 83. https://doi.org/10.1186/s12966-017-0538-3

Schrepp, M., Hinderks, A., & Thomaschewski, J. r. (2017). Construction of a Benchmark for the User Experience Questionnaire (UEQ). *International Journal of Interactive Multimedia and Artificial Intelligence*, *4*(4). https://doi.org/10.9781/ijimai.2017.445

Sparkes, A. C., & Smith, B. (2014). *Qualitative research methods in sport, exercise & health: From process to product*. Routledge.

Stoyanov, S. R., Hides, L., Kavanagh, D. J., & Wilson, H. (2016). Development and Validation of the User Version of the Mobile Application Rating Scale (uMARS). *JMIR Mhealth Uhealth*, *4*(2), e72. https://doi.org/10.2196/mhealth.5849

Taki, S., Lymer, S., Russell, C. G., Campbell, K., Laws, R., Ong, K. L., Elliott, R., & Denney-Wilson, E. (2017). Assessing User Engagement of an mHealth Intervention: Development and Implementation of the Growing Healthy App Engagement Index. *JMIR Mhealth Uhealth*, *5*(6), e89. https://doi.org/10.2196/mhealth.7236

White, I. R., Carpenter, J., & Horton, N. J. (2012). Including all individuals is not enough: Lessons for intention-to-treat analysis. *9*, 396-407. https://doi.org/10.1177/1740774512450098

Figure Legend

Table 1. Outcome measurement and procedures

Table 2. Combined (objective and subjective) Engagement Index

Table 3. Characteristics of study participants

Table 4. Thematic analysis: theme, summary, and example quotation from participants

Figure 1. Sample screenshots from the Zingo App

Figure 2. User Experience Questionnaire benchmarked mean findings for each sub-scale

Supplementary table 1. Interview Schedule

Supplementary table 2. uMARS findings for parents, teachers and therapists and Zingo Experience Questionnaire findings for Parents and Teachers

Table 1. Outcome measurement and procedures

Feasibility Element	Study Outcome	Assessment method	Who	Timepoint	Data analysis and reporting
Fidelity	Adherence to therapy program	Real time in-app data	Child (with adult support as needed)	Throughout 4-week intervention	Proportion, of all therapy prescribed, completed
	Engagement-Objective	Real time in-app data	Child (with adult support as needed)	Throughout 4-week intervention	Engagement Index - amount, frequency, duration and depth of usage
Acceptability	Engagement-Subjective	User Experience Questionnaire (UEQ)	Child (with adult support as needed)	After intervention	Benchmarked data for each UEQ subscale. Engagement Index-subjective
		Semi-structured Interview	Child and parent dyad	After intervention	Thematic analysis
Acceptability and perceived value	App quality	Mobile Application Rating Scale-user version	- Parent - Teacher - Therapist	After intervention	Means and Standard Deviation for each subscale
		Semi-structured Interview	Child and parent dyad	After intervention	Thematic analysis
	User experience	Zingo Experience Questionnaire	- Parent - Teacher	After intervention	Various reporting according to question (see Supplementary 2)
		Semi-structured Interview	Child and parent dyad	After intervention	Thematic analysis
Acceptability	Goal attainment	Canadian Occupational Performance Measure (COPM)	Child and parent dyad	Before and after intervention	COPM pre-post change means, and proportion with a 2-point change

Table 2: Combined (objective and subjective) Engagement Index

	Objective Experience				**Subjective Experience**
	Extent of Usage (app usage data)				User Experience Questionnaire
	Amount	Duration	Breadth	Depth	
What is being measured?	*Frequency of use of Zingo.* Frequency of use of central gamification feature: "looking after" digital pet	*Time spent engaged with Zingo.* Views of therapy activity videos as a proxy for time. (i.e. as app use-time may not reflect actual engagement)	*Whether child accesses all the features of Zingo.* Measuring if all non-mandatory (but important) features of Zingo were used	*Does child engage at intended depth with key features of the app?* Measuring the extent of use of 3 non-mandatory features, as proportion of expected for full engagement	*How do children report on their engagement with the app?* Was it attractive, perspicuous, efficient, dependable, and novel experience that is suitable for children?
Scoring criteria	Count of water, food, love button presses (available after each activity completion)	Count of video watches (max 4) for each activity prescribed. Sum of above / number of activities prescribed. (= score out of max 4)	One score awarded for each of the following: 1. All prescribed activity videos watched ≥1 2. Long version feedback ≥1 3. Water, food, and love all ≥1 4. Viewed "My Stars" progress page ≥1 5. Spent coins in shop ≥1 6. Collected 'stars' sufficient for pet upgrade ≥1	One score awarded for each of the following: 1. Long version feedback count (max 4) / 4 2. "My Stars" screen count (max 8) / 8 3. Number of items purchased (max 4) / 4	User Experience Questionnaire sub-scales. Means for each scale (below) adjusted from a -3 to +3 scale to a 0 to 6 scale. 1. Attractiveness / 6 2. Perspicuity / 6 3. Efficiency / 6 4. Dependability / 6 5. Stimulation / 6 6. Novelty / 6
Section calculation	Sum of above divided by number of activities completed, %	Sum of above divided by 4, %	Sum of above divided by 6, %	Sum of above divided by 3, %	Sum of above divided by 6, %
Section weighting in Engagement Index total	15	15	15	15	40
	Objective Experience = 60%				*Subjective Experience = 40%*

Table 3. Characteristics of study participants

	n=8
Age (years), mean (SD, range)	8.5 (1.6, 6 - 11)
Sex n (%)	
Female	5 (62.5)
Male	3 (37.5)
Diagnosis, n (%)	
Cerebral Palsy (CP)	6 (75.0)
Autism Spectrum Disorder	1 (12.5)
Intellectual Disability	1 (12.5)
CP classification, n (% children with CP)	
hemiplegia	3 (50.0)
diplegia	3 (50.0)
Functional Mobility Scale at 50m, n (%)	
6	2 (25.0)
5	4 (50.0)
4	0 (0.0)
3	0 (0.0)
2	0 (0.0)
1	2 (25.0)
GMFCS, n (% children with CP, n=6)	
I	1 (16.7)
II	4 (66.7)
III	0 (0.0)
IV	1 (16.7)
V	0 (0.0)

Note: SD: Standard Deviation. Functional Mobility Scale (FMS) (Graham et al., 2004) is a tool for the classification of functional mobility in children, with a rating of 6 representing the most independently mobile, and a rating of 1 for children who are the least independently mobile and rely on wheeled mobility. FMS rates mobility at 3 distances: 5m, 50m and 500m; for the purposes of this study we chose to utilize the FMS to rate the participants' mobility over a distance of 50m only. GMFCS: Gross Motor Functional Classification Scale-Expanded and Revised(Palisano et al., 2008), is a functional mobility classification tool suitable for children

with CP. In the GMFCS “Level I” represents the most independently mobile through to “Level V” which represents the least mobile.

Table 4. Thematic analysis: theme, summary, and example quotations from participants

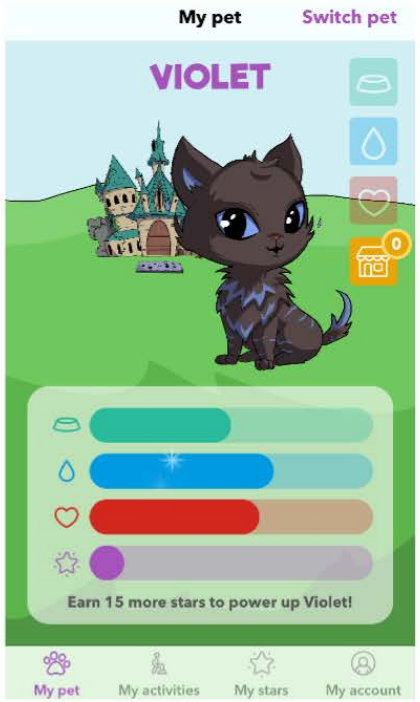
Theme or subtheme	Summary	Example quotations
App as motivator	Children and parents communicated that Zingo was motivating them to complete therapy program activities.	"I like [my activities] because of the Zingo app, I like therapy because of the Zingo app" Child 1 "I [saw] him far more engaged in wanting to do his exercises. When we had the piece of paper stuck to the front of the fridge, even though he was opening the fridge multiple times a day it was still not the same motivation." Parent 2
Fun	Zingo was viewed as helping to make practicing therapy a fun experience for the children, with seven of the participants reported it as being fun. Frequently, this experience of fun was linked to the gamified elements of the game that the children enjoyed.	"[Zingo] makes it more fun when I actually get to play something with [therapy]. It's like a game with it" Child 3 "She loves getting the star and hearing the noise." ("<Plüddemann et al. (in press)_rapid reviews.pdf>,")Parent 3 "…Yeah and I like to, I like to get full rows of things, like the food and stuff." Child 3 "It is very wonderful of how you just see that star counter go more full and more full." Child 1
Autonomy	Children and their parents reported independence with using Zingo and engaging in prescribed therapy activities. Four children reported on either increased confidence with using Zingo, the ability to use it independently, or teaching others how to use it.	" Cause …[a therapy program] on paper I do it with someone, but on the app… I know what to do and I could just do it by myself." Child 4 "…even though they'd spent a considerable amount of time having fun with the app they were still just as interested to go back on either later in the day requesting it again or the next morning straight away back into it." Parent 2 "Did [your teacher] have to help you the first few times?" Parent 4

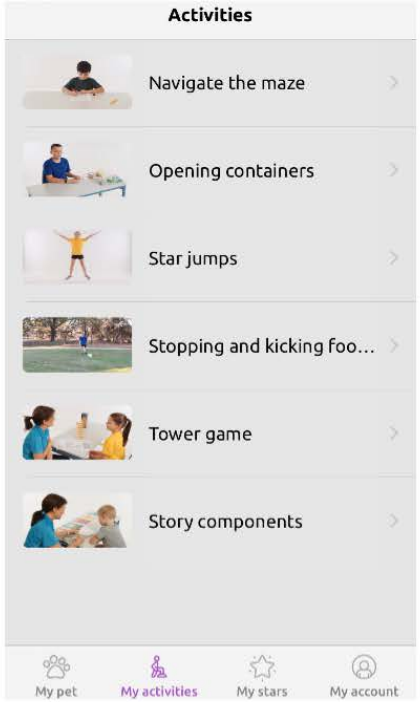
		"No, I had to help her." Child 4 "Cause it was colorful and it's like easy to, kind of easy to find your way around and how to do it by yourself." Child 5
Goal setting and progress -	Children discussed the concept of goals and monitoring progress in two different ways: some referred to the goals for their therapy activities, and others the in-app goals of prescribed activity completion. Six of the children described how Zingo enabled them to monitor their progress.	**In-app goals:** "Did you understand what you have to do to earn the coins?" Interviewer "Like do the exercises a lot so you can actually earn the coins… But the coins are goals so…. you sometimes earn a goal when you've done all the activities." Child 3 "Do you like this feature, being able to look back? Because you like being able to track your records and progress don't you?" Parent 1 "Yeah, even though I don't, like, use it that often, it's just pretty, pretty good." Child 1 **Therapy goals:** "And your goal was to?" Parent 4 "Learn how to skip." Child 4 "So [therapist] broke it down into lots of different, lots of smaller activities… when you put it together it all helped you with your skipping right? Parent 4 "Yeah. And I actually learned how to skip." Child 4
Identifying with digital pet	Children were connected emotionally to their digital pet at different levels; some simply liked one type of pet over another, and others described significant empathy	"Well, I felt like very sad for it because well I didn't really know how, how to like, how to help her feel happy again but then I worked out that I had to do some more exercises to make her happy." Child 3

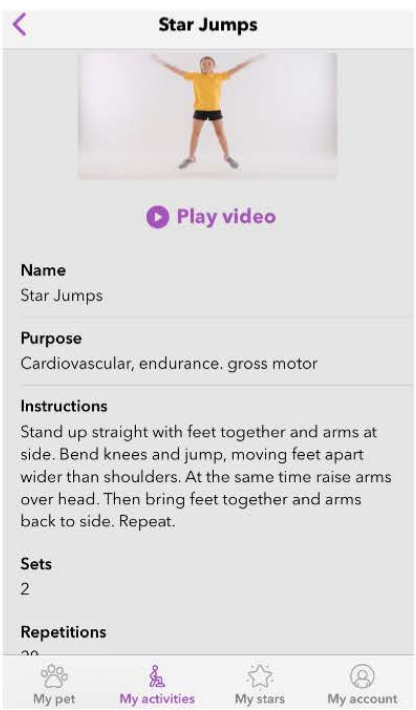
	with their digital pet's emotions. When questioned further on this connection, the children and parents indicated that they understood it was not real and that the child wasn't distressed.	"But we have picked a lot of names for it. I just chose a lot of names, then I chose, [child's own name] because that is my name." Child 3 "The pets overall, as I said, they are… one of my favourite parts of the game, it feels satisfying… I love my pets and I can't look, I can't look it was depressed." Child 1 "Oh, no. Wolfus is sad. Oh no, no, no." Child 1 "When she was very angry, how did that make you feel?" Interviewer "Sad, no, happy… Happy, because she was funny… she was grumpy" Child 6


ZINGO

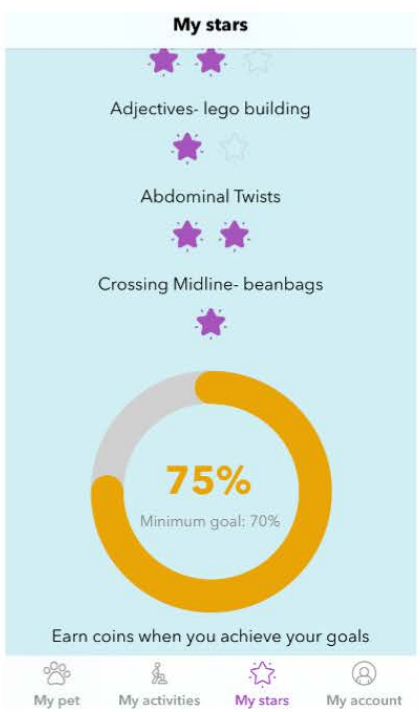

Select your pet
Your pet will help you stay on track with your activities. Keep up with your weekly program, and you'll earn upgrades and other things for your pet.
GO

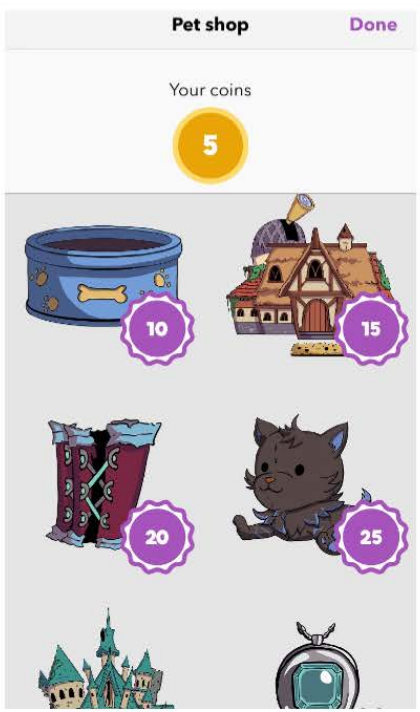

My pet
Switch pet
VIOLET
0
Earn 15 more stars to power up Violet!
My pet
My activities
My stars
My account

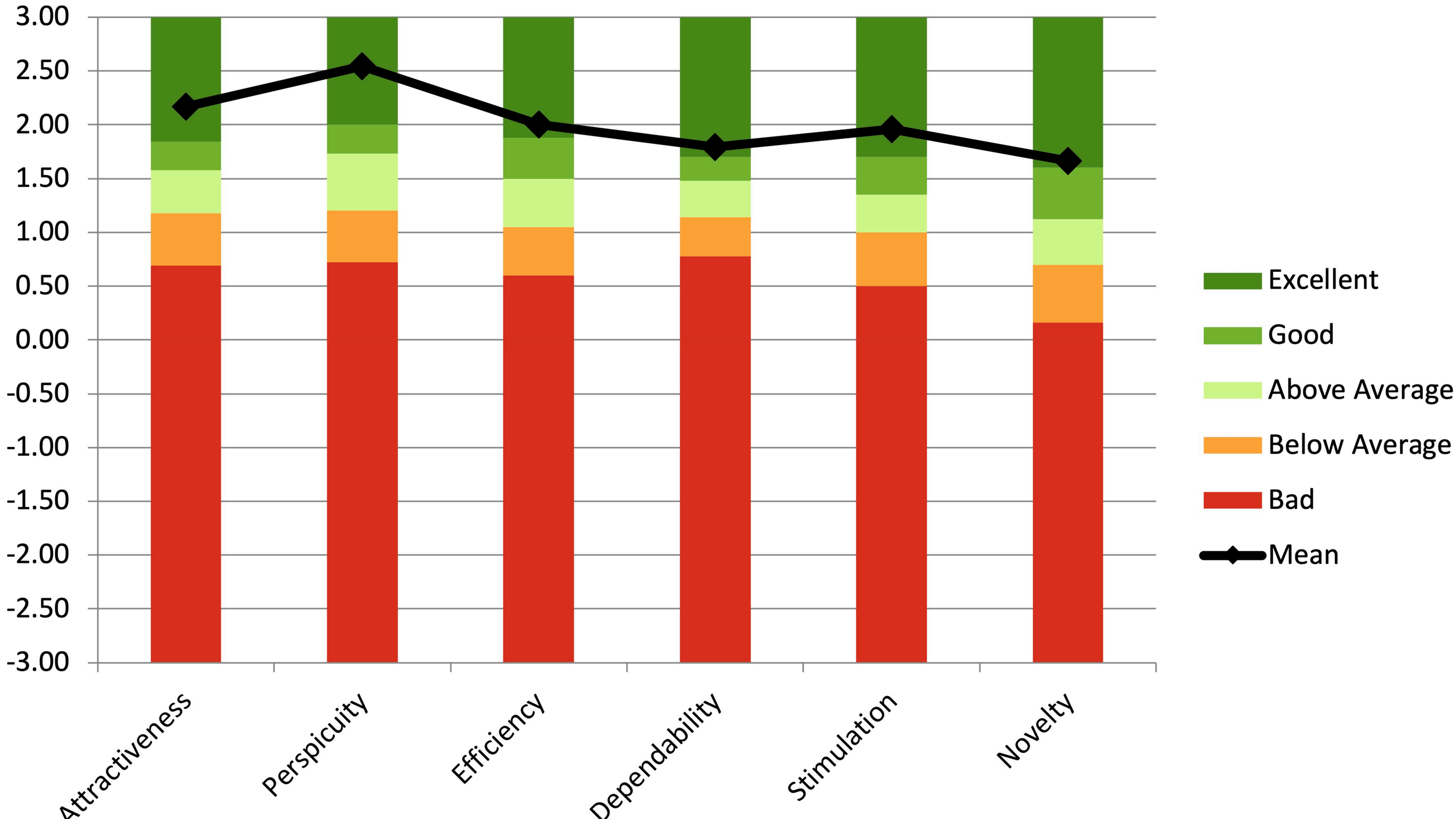

Activities
Navigate the maze
Opening containers
Star jumps
Stopping and kicking foo...
Tower game
Story components
My pet
My activities
My stars
My account


Star Jumps
Play video
Name
Star Jumps
Purpose
Cardiovascular, endurance. gross motor
Instructions
Stand up straight with feet together and arms at side. Bend knees and jump, moving feet apart wider than shoulders. At the same time raise arms over head. Then bring feet together and arms back to side. Repeat.
Sets
2
Repetitions
My pet
My activities
My stars
My account


Cancel
0:10
Finished


My stars
Adjectives- lego building
Abdominal Twists
Crossing Midline- beanbags
75%
Minimum goal: 70%
Earn coins when you achieve your goals
My pet
My activities
My stars
My account


Pet shop
Done
Your coins
5
10
15
20
25


3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
Attractiveness
Perspicuity
Efficiency
Dependability
Stimulation
Novelty
Excellent
Good
Above Average
Below Average
Bad
Mean

Zingo App Participant Interview

Introductions points

- We are primarily seeking _____ *(the child's)* experiences of using the app. But parents are welcome to support the child with their communication, prompt the child, or add their perspective as needed
- Open and honest feedback is really important. Tell us if there's something you didn't like

Usability

- **Tell me about how you used Zingo at home and school over the last 4 weeks?**
  -Prompt re: home & school use as required
  -Did you use a school device or your own one (or both)? (if own: iPad or iPhone)
  How did the app work on that device? (any problems?)
- **How easy, or not easy, was it for you to use ZINGO?**
  (older kids) How easy was it to use Zingo of 10? If 10 is extremely easy and 0 is extremely difficult?
  Why?
- **How long did it take you to feel confident using ZINGO?**
- **When you first started using ZINGO, how much help did you need to figure it out?**
- Is it hard to find what you want to do on ZINGO?
  (e.g. see the activity you want, to see what you've done so far, how far to go, how to go to the shop)
- **Was it ever confusing to know what to do?**
  (i.e. to do activities and look after your pet)

Acceptability

- **What were the best parts about ZINGO?**
- **What were the worst parts about ZINGO?**
- Have you been given a regular therapy program on paper by your therapist before?
  What are the differences between that and using ZINGO?
- What do you think of how the app looks?
  (older kids) good do you think Zingo looks out of 10?
  If 10 is extremely good and 0 is extremely back?
- What do you think about the videos?
  - need to clarify whether child is referring to video from library or custom video
- **Would you recommend this app to your classmates (who needed to do exercise or other therapy practice)? Why?**
- **Do you plan/want to use Zingo in the future? Why?**

Engagement

- **When you were using ZINGO, did it feel like you were doing therapy? Or playing a game?**
- **Did it make you want to do therapy more, less or the same compared to normal?**
  Why?
- Did you ever do the therapy activities, without using the app? Why?
- **What did the Teacher/Education Assistant/ Parent do when you were using the app?**

if more detail needed: **What help did they give?**
Help with making the app work? Help with doing the activity?

How did you feel about that?

- Did your parents talk with you about using the app? (NB parent email updates)
  if yes: **What things did you talk about with your parents?**
  How did you feel about that?
- For parent: Did you hear from therapist after they set it up, did they talk about ZINGO?

Specific feedback for individual elements

Show image of the following screens:

1. My Activities + Individual Activity (program and activity video & instructions)
2. Feedback screens (optional feedback to therapist)
3. My Stars (completion & weekly goal monitoring)
4. My Account (Name & email details)
5. My Pet (primary game screen)
6. Swap Pet (additional game function)
7. Shop (additional game function)

- **Tell me about this part of ZINGO?**

If not a suitable / full answer can ask some of:

- **Did you use it?**
- How often
- How did you use it?
- **What did you think about it?**
- How did it work?
- Was it interesting? Or not?
  (can rate out of 10)
- Did it help you to understand what to do?

Specific to 4 & 5

- What pet did you chose? Why?
- Did you change pets along the journey? Why?
- What was it like looking after your pet with the foot, water, and love buttons?
- Was it difficult keeping your pet happy?
- Did you ever upgrade a pet to a bigger version (by filling up the “star bar”)?
- What was that like?
- Do you have any other thoughts about the pets?

Specific to 6

- Did you earn coins using the app?
- Do you understand what you have to do to earn coins?
- What do you think about earning coins that way?
- Did you spend the coins to buy gear and houses in the shop?
- What did you think about the shopping and gear you can buy?

To finish:

Anything else that you would like to tell us about using ZINGO app?

Supplementary table 2. Mobile Application Rating Scale findings for parents, teachers and therapists and Zingo Experience Questionnaire findings for Parents and Teachers

uMARS app Quality ratings (1 – 5)	**Parents Mean (SD) (n=6)**	**Teachers Mean (SD) (n=5)**	**Therapists Mean (SD) (n=6)**
Engagement	4.5 (0.6)	4.1 (0.9)	4.5 (0.6)
Functionality	4.7 (0.5)	4.7 (0.4)	4.2 (0.5)
Aesthetics	4.4 (0.5)	4.7 (0.5)	4.3 (0.7)
Information quality	4.7 (0.5)	4.8 (0.4)	4.5 (0.5)
Total Objective Quality Score	**4.6 (0.5)**	**4.6 (0.7)**	**4.4 (0.6)**

Zingo App Experience Questionnaire – Part 1 (Agree or Disagree)	**Parents Count (%) (n = 7)**	**Teachers Count (%) (n = 5)**
1. By the end of the 4-week trial, your child understood how to use the app - even if they needed physical assistance	Agree: 7 (100%) Disagree: 0 (0%)	Agree: 5 (100%) Disagree: 0 (0%)
2. By the end of the 4-week trial, your child used Zingo by him/herself - no physical assistance needed with device	Agree: 6 (86%) Disagree: 1 (14%)	Agree: 4 (80%) Disagree: 1 (20%)
3. By the end of the 4-week trial, your child was able to complete the therapy activities without assistance	Agree: 4 (57%) Disagree: 3 (43%)	Agree: 3 (60%) Disagree: 2 (40%)

Zingo App Experience Questionnaire – Part 2 (1 – 5, 1= strongly disagree, 5= strongly agree)	**Parents Median (IRQ) (n = 6)**	**Teachers Median (IRQ) (n = 5)**
1. There was enough time to complete all activities recommended in the app	4.0 (4, 4.8)	5.0 (4.0, 5.0)
2. The app made completing activities more difficult	1.5 (1.0, 2.0)	2.0 (1.0, 2.0)
3. I understood how to use the app	4.5 (4.0, 5.0)	4.0 (4.0, 4.0)
4. I enjoyed using the app with my child	5.0 (5.0, 5.0)	5.0 (4.0, 5.0)

5.	My child was interested in using the app at the beginning of the 4-week period	5.0 (5.0, 5.0)	4.0 (4.0, 5.0)
6.	The app motivated her/him to do therapy activities at the beginning	5.0 (4.2, 5.0)	5.0 (4.0, 5.0)
7.	My child was still interested in using the app at the end of the 4-week period	5.0 (3.5, 5.0)	4.0 (3.8, 4.2)
8.	The app motivated the him/her to do therapy activities at the end	5.0 (3.5, 5.0)	4.0 (3.8, 4.2)

Note: uMARS: Mobile Application Rating Scale- User version. SD: Standard Deviation. n: number of participants who completed questionnaire. IRQ: Inter Quartile Range.