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Feasibility of using touch screen technology for early cognitive assessment in children

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ABSTRACT

Objective To explore the feasibility of using a touch screen assessment tool to measure cognitive capacity in toddlers.

Design 112 typically developing children with a median age of 31 months (IQR: 26–34) interacted with a touch screen cognitive assessment tool. We examined the sensitivity of the tool to age-related changes in cognition by comparing the number of items completed, speed of task completion and accuracy in two age groups; 24–29 months versus 30–36 months.

Results Children aged 30–36 months completed more tasks (median: 18, IQR: 18–18) than those aged 24–29 months (median: 17, IQR: 15–18). Older children also completed two of the three working memory tasks and an object permanence task faster than their younger peers. Children became faster at completing the working memory items with each exposure and registered similar completion times on the hidden object retrieval items, despite task demands being twofold on the second exposure. A novel item required children to integrate what they had learnt on preceding items. The older group was more likely to complete this item and to do so faster than the younger group.

Conclusions Children as young as 24 months can complete items requiring cognitive engagement on a touch screen device, with no verbal instruction and minimal child–administrator interaction. This paves the way for using touch screen technology for language and administrator independent developmental assessment in toddlers.

What is already known on this topic?

- ► Early identification of cognitive delay is critical if developmental interventions are to commence in childhood.
- ► Measurement of cognitive ability is currently heavily reliant on language and motor skills and child–administrator interaction.
- ► Use of touch screen devices is increasing and children aged 12 months or younger have the requisite fine motor skills to engage purposefully with touch screens.

What this study adds?

- ► Children as young as 24 months old can complete a cognitive assessment on a touch screen device with no verbal instruction and minimal child–administrator interaction.
- ► Children can learn how to complete cognitive tasks on a touch screen device.
- ► This paves the way for using touch screen technology for language and administrator independent developmental assessment in toddlers.

INTRODUCTION

Perinatal events may lead to long-term neurocognitive deficits, which contribute to a large global burden of disease.[1] The assessment of cognitive ability in very young children is crucial for meaningful quantification of outcome, but can be extremely difficult.[2 3] Executive functions may be poorly differentiated and are difficult to quantify at this age.[4] Validated neurodevelopmental assessments, such as the Bayley Scales of Toddler and Infant Development or the Griffiths Mental Development Scale,[5] rely heavily on children's receptive communication and fine motor skills. Significant child–administrator interaction is often required with resultant intra-assessor variability. Although non-verbal assessment tools are available for use with older children, none are available for children under the age of 3. Additionally, there is a paucity of cognitive assessment tools that are suitable for use with children with physical disabilities and limited fine motor skills.[3 6] A computerised cognitive assessment tool that is less reliant on receptive communication and fine motor abilities would be critical to addressing this gap. Validated computerised cognitive assessment tools (eg, Cambridge Neuropsychological Test Automated Battery)[7 8] are currently only available for use with older children and adults.

We, among others, have shown that today's children are spending increasing amounts of time interacting with touch screen devices.[9 10] Between 44% and 77% of children under the age of 2 have interacted with a mobile device.[11] Parents report that children engage meaningfully with touch screen applications from 12 months of age, and touch screen skills and interactions improve with age.[2 10] This observation opens up the potential application of touch screen devices for both assessment and early intervention in toddlers.[10] With this in mind, we explored the potential of a touch screen assessment tool to assess cognitive functions in children aged 2–3 years.

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METHODS

Participants

We aimed to recruit typically developing children aged between 24 and 36 months to the study. All staff at the National University of Ireland, Cork, and of the Health Service Executive in Ireland were invited to participate in the study via an email sent through the executive mailing systems. Those contacted received a participant information leaflet, a parental questionnaire and an informed consent form. Parents who wished to participate were asked to complete and bring the documents to the appointment. At the time of birth, mothers were on average 34 years of age (median: 34; IQR: 31.5–37). Of the 105 parental questionnaires returned, 95% (100/105) of the children's biological parents were living together at the time of the assessment. Eighty-two per cent (86/105) and 68% (71/105) of the children's mothers and fathers, respectively, reported having a university education. Children were excluded from the study if they had a developmental delay or neurological disorder. The study was approved by the National University of Ireland, Cork Ethics Committee and the Clinical Research Ethics Committee of the Cork Teaching Hospitals, and was carried out in accordance with Good Clinical Practice guidelines.

The Babyscreen software application

The Babyscreen software application V.1.5 (Hello Games, Guildford, UK) was developed to investigate the feasibility of using a touch screen assessment to measure cognitive abilities in very young children. A recent study has demonstrated that in children aged 2–4 years, all 2-year-olds could tap and drag or slide and all 3-year-olds could tap, drag, and slide, and drag and drop.[12] With these observations in mind, we limited the requirement for more complex touch screen gestures in the prototype and opted to progress motor complexity slowly through the tasks.

The cognitive tasks were designed to assess children aged 12–36 months. Although it was never our intention to assess children as young as 12 months, the tool needed to be able to reliably assess children as young as 18 months who may be exhibiting delays. The cognitive tasks were based loosely on existing tasks in the literature and were adapted for use with a touch screen device and a toddler cohort. They were designed to stimulate the child's auditory, visual and kinaesthetic systems, and thus encourage high levels of engagement and learning (see table 1 and figure 1 for description of tasks).

Measuring performance on the Babyscreen software application

The Babyscreen yields three performance variables: the number of items completed, the speed of item completion and accuracy (items where distractor stimuli were present). The number of items completed reflects the total number of items completed out of a possible 18. For each item, a completion time for the first and second (if required) attempts was recorded in seconds and total completion time for each item was calculated as the sum of the two attempt times. Children who failed a Babyscreen item were automatically assigned a completion time of 0 s such that they were initially treated as missing values, and thus excluded from the completion time analyses. However, in doing this, we were excluding a subset of particularly poor performers in which we were especially interested. For this reason, we adopted a 'penalisation approach' where participants who failed an item were assigned the maximum completion time value across all participants on that item. While the approach renders the completion times meaningless in terms of their numeric value, it enables a quantification of performance that does not exclude the worst performers.

Participants received an accuracy score on the items in which the child had to choose between multiple onscreen objects (target and distractor stimuli; eg, items 4–11, 13 and 18). On completed items, an accuracy score was calculated based on whether the child completed the item on the first or second attempt, and whether they initially pressed a target or distractor stimulus on the successful attempt.

Data acquisition

The Babyscreen was administered on an Apple iPad 2.0 set to 70% of the maximum volume, placed flat and affixed to the table using double-sided tape. The child's age in months, sex, previous usage of touch screen devices, average minutes per use of touch screen devices per week, and parental opinion of normal or abnormal development to date were entered into the Babyscreen application by the assessor. For the first training item, the assessor gave the child a visual demonstration by slowly showing them how to complete the task. The child was then given two opportunities to complete the item. If he/she could not complete the item on the first attempt the assessor gave a second visual demonstration along with a second opportunity to complete the item. If the child still could not complete the item on the second attempt, he/she nonetheless proceeded to the next item. On all remaining items, the procedure was the same except that a visual demonstration was not given to the child before his/her first attempt at completion.

Table 1 Origins of prototype cognitive tasks designed to measure cognitive functioning in very young children

Cognitive construct	Design of prototype cognitive tasks
Training items	The tasks familiarised children with the format of the assessment and encouraged them to complete the items without verbal instructions from the assessor.
Selective attention	The measure was loosely based on the Picture Deletion Test for Preschoolers[21] and required the child to selectively respond to the target star while inhibiting a response to the distractor stars. In an effort to make the task age appropriate for use with a toddler population, we only used one array of targets and non-targets and one target stimulus in any one array.
Working memory	The measure was loosely based on a hidden object retrieval paradigm.[22] A gold target star fell onscreen and was concealed by a blue or red cup. The children had to search in the correct location and press the star until it disappeared from the screen which signalled item completion. To explore a learning effect, children were presented with the same working memory task on three separate occasions (items 10, 11 and 13).
Hidden object retrieval and object permanence	The tasks examined children's ability to complete novel tasks. The aim was to build to the point of asking the child to complete a one-step, then a two-step and then a three-step task. To explore a learning effect, children were presented with the same hidden object retrieval and object permanence items on two occasions. On the second occasion, the task demands were twofold such that the child had to complete the process twice before they could proceed to the next item.
Learning item	Item 17 was a novel item which required children to integrate the skills they had learnt on preceding items to successfully complete a three-step task.

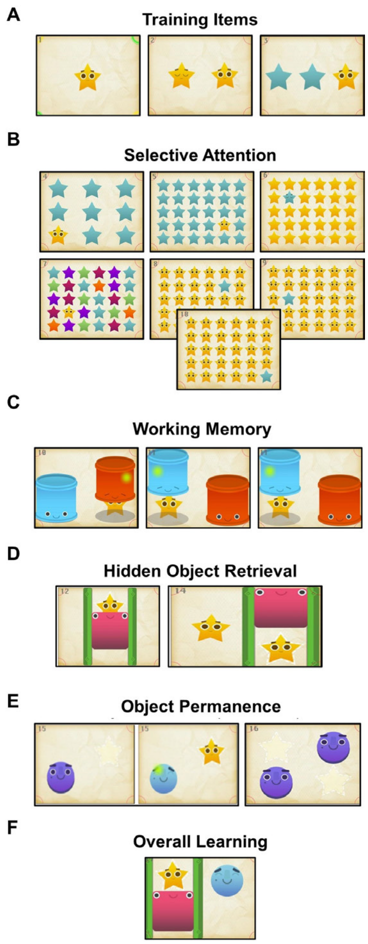

Figure 1 Schematic of the items on the Babyscreen software application. (A) Items 1–3 were training items which taught the child that the gold star with the face was the target such that pressing it would complete the item and facilitate progression to the next item. (B) Items 4–7 required the child to selectively attend to the correct target star while inhibiting a response to the distractor stimuli. The target changed on an item-by-item basis and difficulty was modulated by changing the colour of the stimuli and by increasing number of distractors present onscreen. (C) Items 10, 11 and 13 aimed to examine working memory. On all three items, a target gold star was presented onscreen. Two cups, one blue and one red, fell from the top of the screen one of which covered the star. The child had to interact with the correct cup to reveal the target and then press it until it disappeared from the screen which signalled item completion. (D) Items 12 and 14 required the child to retrieve a hidden object. A target gold star was presented onscreen which was subsequently hidden by a red box. The child needed to move the red box downwards to reveal the target and press it until it disappeared from the screen which signalled item completion. The item demands were twofold on item 14; the child had to complete the process twice before they could proceed to the next item. (E) Items 15 and 16 were designed to measure a child's understanding of object permanence. A blue button with a smiling face along with an outline of a star was presented onscreen. Pressing the blue button would cause a target gold star to appear. The item required the child to hold the blue button and simultaneously interact with the target gold star until it disappeared from the screen which again signalled item completion. The item demands were twofold on item 16; the child had to complete the process twice before he/she could proceed to the next item. (F) Item 17 was an overall measure of learning. Children had to recall what they learnt on the hidden object retrieval and object permanence items to complete the item.

To explore a learning effect, children were presented with the same working memory task on three separate occasions (items 10, 11 and 13) and with similar hidden object retrieval (items 12 and 14) and object permanence items (15 and 16) on two occasions, respectively. On the second exposure of the hidden object retrieval and of the object permanence measures the task demands were twofold. Despite the similarity in the items tapping into the three constructs, each item was treated individually and the child was given two opportunities to complete it. In all cases, the session was terminated if the child became distressed or tired.

Statistical analyses

Descriptive data are presented as mean (SD) or median (IQR) as appropriate. A series of non-parametric X^2 tests and Mann-Whitney U tests were used to assess the impact of age group on the three core performance measures. A series of Wilcoxon signed-rank tests were used to access change in completion time or accuracy for repeated exposures to items. The internal reliability of the Babyscreen measure and its constituent subscales was assessed using Cronbach's alpha. An alpha value of 0.05 was used to determine statistical significance. In many cases, a Bonferroni correction was applied as several comparisons were being performed simultaneously. Where appropriate, where a result is statistically significant, a p value of <0.05 is reported along with a statement pertaining to whether or not the result survived the correction for multiple comparisons.

RESULTS

Of 144 children recruited, three were excluded due to existing developmental concerns and 29 withdrew prior to attending the assessment appointment, yielding a final sample of 112 children (60 female), with a median age of 31 months (IQR: 26–34). The sample was divided into two groups based on the children's age in months (24–29 months and 30–36 months).

Group 1 comprised 55 children (27 female) aged between 24 and 29 months (median: 26; IQR: 25–28) and group 2 comprised 57 children (33 female) aged between 30 and 36 months (median: 34; IQR: 32–35). Overall, 95.5% of parents indicated that English was their child's first language. There were no significant differences between the two age groups in sex, birth weight, gestational age and first language (all $p>0.05$).

Previous touch screen device use

Overall, 91% (102/112) of parents reported that their toddler used a touch screen device at home for a median time of 10 min/day (IQR: 5–20). Thirty-one per cent of parents (35/112) reported that their child used a touch screen device on a daily basis, 30% (33/112) used a touch screen device two to three times per week, 30% (34/112) reported occasional use and 9% (10/112) reported never using a touch screen device at home. There were no significant differences in the frequency of touch screen use as a function of age group or sex (both $p>0.05$).

Age-related changes in cognition

There was a linear increase in the number of Babyscreen items completed ($r_s=0.44$, $p<0.05$) and the number of items completed without a visual demonstration ($r_s=0.3$, $p=0.05$) as a function of the children's age in months. Across all children, the median number of Babyscreen items completed was 18 (IQR: 16–18) and the number completed without a visual demonstration was 16 (IQR: 14–17).

Children aged 30–36 months completed more items (median: 18, IQR: 18–18) than those aged 24–29 months (median: 17, IQR: 15–18; p<0.05). Older children also completed more items without a visual demonstration (median: 16, IQR: 14–17) than their younger peers (median: 15, IQR: 13–16; p<0.05). In both age groups, the number of items completed was not associated with the child's native language, previous touch screen use or the parental level of educational attainment (all p>0.05).

Training tasks (items 1–3)

Training items allowed the child to learn what was required to progress further in the assessment. In both age groups, the rate of successful completion of item 1 following a visual demonstration was 98.1% (see supplementary table S1).

Age-related changes in selective attention (items 4–9 and 18)

More than 90% of children across both age groups were able to complete the selective attention items without a visual demonstration. There was no difference in the rates of selective attention item completion, speed of item completion or accuracy between the two groups when corrected for multiple comparisons (all p>0.05).

Age-related changes in working memory (items 10, 11 and 13)

On the first iteration of the working memory item, 67% of 24–29 month olds and 70% of 30–36 month olds completed the item without a demonstration. On the second iteration, the ability to complete the item increased to 78.4% in the younger age group and 94.7% in the older age group, respectively. Consistent with a learning effect, all children became progressively faster at completing the item with increased exposure (all p<0.05). The children aged 30–36 months performed the working memory items faster than those aged 24–29 months on each iteration, and significantly so on the second and third exposures (both p<0.05; see table 2). Children aged 30–36 months were more accurate than those aged 24–29 months on two of the three items of working memory (items 10 and 11), but only significantly so on item 11 (p<0.05).

Age-related changes in hidden object retrieval (items 12 and 14)

Rates of completion without demonstration on the first exposure to the hidden object retrieval item were high; 76.4% and 80.7% in the 24–29 and 30–36 month age groups, respectively. At second exposure, the completion rates increased to 92.7% and 94.7% for each group, respectively. It follows that there was no significant difference in the rates of successful hidden object retrieval item completion as a function of age group. Children demonstrated learning on the measures of hidden object retrieval such that similar completion times were observed on the two iterations of the item despite the fact that the task demands were twofold on the second exposure (p>0.05). There was a trend towards the older children completing task 14 significantly faster than their younger counterparts, but the result did not reach statistical significance (p>0.05).

Age-related changes in an understanding of object permanence (items 15 and 16)

These items presented a greater challenge to the younger children as evidenced by lower rates of completion. For example, without a visual demonstration 49.1% of younger children and 64.9% of older children completed the item. Following a visual demonstration, the rates increased to 62.7% and 94.7% of children for the younger and older age groups, respectively.

Table 2 Comparison of speed of task completion on the 18 items of Babyscreen measure for children aged 24–29 months versus children aged 30–36 months

Cognitive construct	Speed of task completion(s) Median (IQR)	Median difference in speed of task completion between two groups	95% CI for median	P values
Item 1 (training item)				
24–29 months	29.75 (14.75–46.89)		21.75 to 39.0	
30–36 months	27.64 (18.08–44.4)	2.11	21.45 to 34.87	0.97
Item 2 (training item)				
24–29 months	13.7 (6.25–29.53)		9.02 to 19.28	
30–36 months	15.78 (8.83–26.52)	2.08	11.73 to 18.55	0.64
Item 3 (training item)				
24–29 months	3.62 (1.78–7.18)		2.2 to 5.2	
30–36 months	6.45 (2.81–12.34)	2.83	3.58 to 9.25	0.063
Item 4 (selective attention)				
24–29 months	4.72 (1.3–9.32)		2.57 to 6.2	
30–36 months	4.48 (2.18–13.41)	0.24	2.63 to 6.5	0.38
Item 5 (selective attention)				
24–29 months	3.53 (1.77–8.38)		2.48 to 5.48	
30–36 months	3.25 (1.86–5.1)	0.28	2.45 to 4.22	0.66
Item 6 (selective attention)				
24–29 months	4.73 (1.93–8.77)		3.38 to 5.98	
30–36 months	4.12 (2.43–7.13)	0.61	3.29 to 5.52	0.82
Item 7 (selective attention)				
24–29 months	3.6 (1.82–8.45)		2.37 to 5.38	
30–36 months	3.35 (2.08–6.19)	0.25	3.03 to 4.01	0.71
Item 8 (selective attention)				
24–29 months	8.27 (4.92–31.05)		6.8 to 16.7	
30–36 months	21.23 (9.84–38.9)	12.96	15.7 to 33.7	0.023*
Item 9 (selective attention)				
24–29 months	6.77 (1.61–23.37)		3.1 to 12.8	
30–36 months	3.82 (2.47–7.62)	2.95	3.2 to 5.1	0.25
Item 10 (working memory)				
24–29 months	36.68 (18.25–64.45)		27.9 to 50.4	
30–36 months	28.9 (13.66–46.61)	7.78	18.2 to 36.4	0.089
Item 11 (working memory)				
24–29 months	24.35 (8.38–41.94)		14.7 to 32.9	
30–36 months	7.87 (5.15–15.04)	16.48	6.4 to 12.4	0.0001*
Item 12 (hidden object retrieval)				
24–29 months	13.12 (6.4–38.12)		8.4 to 24.4	
30–36 months	8.35 (5.18–20.67)	4.77	6.4 to 10.1	0.093
Item 13 (working memory)				
24–29 months	10.73 (6.07–21.7)		7.95 to 17.5	
30–36 months	5.82 (4.53–9.65)	4.91	5.5 to 7.1	0.001*
Item 14 (hidden object retrieval)				
24–29 months	12.68 (7.23–26.92)		8.2 to 18.1	
30–36 months	9.033 (6.45–14.20)	3.65	7.7 to 10.7	0.058
Item 15 (object permanence)				
24–29 months	47.19 (19.73–65.34)		34.98 to 53.6	
30–36 months	26.58 (13.45–60.05)	20.61	17.8 to 46.3	0.13
Item 16 (object permanence)				
24–29 months	72.17 (28.89–167.64)		44.5 to 167.6	
30–36 months	30.32 (15.61–73.65)	41.85	18.3 to 51.4	0.003*
Item 17 (combined learning)				
24–29 months	35.45 (18.75–136.59)		24.9 to 109.9	
30–36 months	18.95 (12.46–48.05)	16.5	15.4 to 28.6	0.005*
Item 18 (selective attention)				
24–29 months	3.9 (2.1–19.20)		2.7 to 5.9	
30–36 months	3.82 (2.09–6.33)	0.08	3.0 to 4.6	0.58

*P<0.05.

There was no significant difference in completion times on the first exposure of the item as a function of age group ($p>0.05$). However, indicative of greater learning in the 30–36 months old group, these children completed the second exposure of the item significantly faster than the younger group ($p<0.05$).

Combined measure of learning (item 17)

The combined measure of learning differentiated between the two age groups such that the older group was more likely to complete the item ($p=0.003$) and to do so faster than the younger group ($p<0.05$; see table 2).

Internal reliability of the Babyscreen

The Babyscreen registered good 'overall' internal consistency, $\alpha=0.85$. All 18 items were worthy of retention, the greatest increase in alpha would come from deleting item 16, which would increase alpha by 0.009. The selective attention subscale also had reasonable internal consistency, $\alpha=0.81$. However, the working memory, hidden object retrieval and object permanence subscales lacked consistency ($\alpha=0.58$, $\alpha=0.55$ and $\alpha=0.43$, respectively). The poor internal reliability of the constructs is discussed below.

DISCUSSION

We have shown, for the first time, that children as young as 2 years old can complete cognitive tasks presented on a touch screen device with no verbal instruction and minimal child–administrator interaction. Current neurodevelopment assessments are highly contingent on a child's receptive communication and fine motor skills, and a high volume of child–administrator interaction is often required.[3] While computerised cognitive assessment undoubtedly has the potential to surmount these limitations, none are currently available for children under the age of 3. The reciprocity of the touch screen assessment enabled them to learn how to complete novel cognitive tasks very quickly with no verbal instruction or adult engagement. So much so that children as young as 24 months demonstrated improved performance with repeated exposure to stimuli. Reciprocity is an important vehicle for learning and is critical to making social contexts a rich learning ground for children.[2 13] For example, young children naturally elicit social interaction through babbling, familial expressions and gestures, and adults naturally respond with similar vocalisations and gestures. The 'serve and return' interaction between children has a fundamental role in moulding the architecture of the developing brain.[13] One of the main obstacles to studying executive functions in very young children is the lack of age-appropriate tasks.[14 15] Here, we designed a suite of tasks to stimulate the child's auditory, visual and kinaesthetic systems, and thus encourage high levels of engagement and learning. Our data reveal that basic interactive tasks issued with minimal verbal instruction or administrator engagement can tap into age-related changes in cognition in children aged between 2 and 3 years. Consistent with the literature, we demonstrate that 30–36 month old children perform better on working memory and object permanence tasks than those aged 24–29 months.[14] The combined measure of learning differentiated between the two age groups such that the older group was more likely to complete the item and to do so faster than their younger peers. This suggests that children aged 30–36 months were better able to integrate their new skills.

The 'overall' internal consistency of the Babyscreen suggests that it is successfully tapping into a unidimensional factor such as general cognitive ability or learning. However, it did not reliably capture individual psychological constructs such as working memory, hidden object retrieval and object permanence. The lack of internal consistency on the subscales was likely driven, in part, by variations in the novelty and complexity on each iteration of the tasks. That is, while the tasks were novel to the child on the first exposure, they were not by the second or third exposure. Second, the hidden object retrieval and object permanence tasks were more taxing on the second exposure as the child had to carry out the cognitive operation twice (instead of once). Children may have recruited additional cognitive processes to complete the novel and more complex items, so much so that performance across repeated exposures to a task measuring the 'same construct' did not correlate.

The present study was a feasibility study designed to assess whether or not children could engage meaningfully with a cognitive assessment presented on a touch screen. The tasks were prototypes based loosely on existing tasks in the literature and were not specifically designed to measure the precursors of executive function in children under the age of 3.[16] On reflection, the prototype tasks ultimately were not a good measure of the constructs they were purported to assess. For example, the selective attention items were more akin to measures of processing speed as although the children were trained to respond differentially to target and non-target stars; the outcome measure did not take into account commission errors (press made to distractor stimuli) such that we cannot be certain that the children were selectively attending to targets. Similarly, the working memory items may be more accurately defined as a measure of short-term memory as the children simply had to hold information in mind to complete the task; they did not need to manipulate it in order to achieve the goal of locating the star.[4 14]

It is problematic that children's performance on the assessment was at ceiling levels with most children completing most tasks. This suggests that the tasks were too easy for our targeted age range and that more complex ones will be needed to tap into age-related changes in cognition. For example, unlike most working memory paradigms which invoke a delay period before the child is allowed to search for the hidden object, our children were allowed to search for the target immediately. Diamond[17] suggests that children as young as 10–12 months can successfully retrieve an object they see hidden first at place A and then at place B even after a 5 s delay between hiding and retrieval. While the present study suggests that it is possible to use touch screen technology for cognitive assessment, tasks must be designed that reliably tap into predefined and operationalised cognitive constructs.

Paediatricians currently screen for disability using the observation of psychosocial, cognitive, language and motor developmental milestones. These milestones are surrogate markers of brain development and do not offer any direct insight into the cognitive skills of the child. A computerised cognitive assessment tool could shed light on the emerging cognition of the child if it could directly and reliably measure executive functions. The key constructs of executive function have been shown to predict later cognitive ability, with measurement at preschool age correlating significantly with measured IQ at 11 years.[18] Detection of disability is difficult without formal assessment.[6 19] Even well-validated parental reports measured are not diagnostic and their values lie in identifying children in need of formal developmental assessment.[6] Formal testing is time consuming, requires expert assessors and therefore often is not available in clinics.[6] A quick and reliable cognitive assessment tool that could be administered in clinics would allow for early identification of cognitive delay.

As outlined, our study was not without its limitations and it is also important to highlight that a high proportion of children included in the study were born to parents with a university education such that the sample may not be reflective of a more general population. This is especially relevant as parental education levels are known to be associated with child achievement and cognitive attainment.[20] On a similar vein, while our analyses indicate that a child's cognitive skills as measured by the Babyscreen are independent of the frequency of touch screen use, it remains to be determined how children in low-income environments and countries will perform on the assessment having potentially no prior exposure to touch screen technology .

Future studies involving the Babyscreen will strive to include better designed tasks targeted at the foundational components of executive function in children under the age of 3 and to recruit more heterogeneous samples in terms of educational attainment and socioeconomic status.

Contributors CW, CA, RM, MDH, NM and DMM contributed to the research design and protocol development. CW recruited the participants and performed the assessments. DMT, CW and DMM analysed the data. DMT, CW, CA, RM, MDH, NM and DMM prepared, edited and contributed to the manuscript preparation.

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