

**Can Western developmental screening tools be modified for use in a rural Malawian setting?**

**M.J. Gladstone, MBChB, BSc, MRCPCH<sup>1</sup>, G.A Lancaster, BSc, MSc, PhD<sup>2</sup> A.P. Jones, BSc, MSc<sup>2</sup>, K. Maleta, MBBS, PhD<sup>3</sup>, E. Mtitimila, MBBS, BSc, MRCP<sup>4</sup>, P. Ashorn, MD<sup>4</sup> and R.L. Smyth, MA, MBBS, MD, FRCPC<sup>5</sup>.**

<sup>1</sup>Department of Paediatrics, College of Medicine, Blantyre, Malawi.

<sup>2</sup>Centre for Medical Statistics and Health Evaluation, University of Liverpool, U.K

<sup>3</sup>Department of Community Health, College of Medicine, Blantyre, Malawi.

<sup>4</sup>Department of International Health, University of Tampere Medical School, Finland and Department of Paediatrics, Tampere University Hospital, Finland

<sup>5</sup> Institute of Child and Reproductive Health, University of Liverpool, U.K.

**Corresponding author:**

**Dr Melissa Gladstone  
Institute of Child Health  
University of Liverpool,  
Royal Liverpool Children's Hospital  
Eaton Rd, Liverpool, L12 2AP  
email: mgladstone@btinternet.com**

**Reprint requests: To above corresponding author.**

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**Objective:** To create a more culturally relevant developmental assessment tool for use on children in rural Africa.

**Design:** Through focus groups, piloting work and validation, a more culturally appropriate developmental tool, based on the style of the Denver II, was created. Age standardized norms were estimated using 1130 normal children of 0-6 years from a rural setting in Malawi. The performance of each item in the tool was examined through goodness of fit on logistic regression, reliability and interpretability at consensus meeting. The instrument was revised with removal of items performing poorly.

**Results:** An assessment tool with 138 items was created. Face, content and respondent validity was demonstrated. At consensus meeting 97% (33/34) of gross motor items were retained in comparison to 51% (18/35) of social items. 86% (69/80) of items from the Denver II or DDST were retained in comparison to 69% (32/46) of the newly created items, many of these having poor reliability and goodness of fit. Gender had an effect on 23% (8/35) of the social items, which were removed. Items not attained by 6 years came entirely from the Denver II fine motor section (4/34). Overall, 110 of the 138 items (80%) were retained in the revised instrument with some items needing further modification.

**Conclusions:** When creating developmental tools for a rural African setting, many items from Western tools can be adapted. The “gross motor” domain is more culturally adaptable, whereas social development is difficult to adapt and is culturally specific.

#### **What is already known on this subject:**

- The ages of attainment of developmental milestones can differ with the cultural background of the child, although there is very little data from Africa.
- Developmental assessment in African settings is often done using translated and adapted Western tools, with a dearth of tools adapted, validated and standardized specifically for rural African children.

#### **What this study adds:**

A procedure using validity, reliability, goodness of fit on logistic regression and expert consensus has been devised for assessing newly created questions or items adapted or taken from Western developmental assessment tools.

- Many items from Western developmental assessment tools can work in a rural African setting. Gross motor items are most reliable whereas items within the social area of development need to account for cultural differences.

Eighty percent of the world's disabled population live in low income countries, many of these in Africa.<sup>1</sup> The World Health Organization has made early identification of children with disabilities a high priority, especially as early rehabilitation may reduce the impact of impairments.<sup>2,3</sup> To identify these children and provide basic services, developmental milestones need to be clearly identified. Furthermore, clinical studies investigating interventions on children require normal parameters.

When child development is assessed in clinical studies in developing countries, Western developmental tools are often utilised<sup>4,5</sup>. These include the Bayley Scales<sup>6</sup>, the Griffith's<sup>7</sup>, the McCarthy Scales<sup>8</sup> or the Denver II<sup>9</sup>, all designed and validated in Western countries. These tools may be tailored for use in non-Western settings. Often translation (changing of the language used) is all that is carried out<sup>10,11</sup>. If this is not accompanied by a process of adaptation, translation alone may not allow completely for local expressions and customs therefore leading to misinterpretation of results<sup>12</sup>. In other settings, tools are adapted and items are modified and in some cases new items are created to use within a Western tool<sup>13</sup>. Sometimes these tools are piloted (tried out before use)<sup>14</sup> and validated (assessment that they are measuring what they are supposed to be measuring) in the local population<sup>15</sup>. Even these adapted tools however, are of limited value without normal ranges for their defined population. Standardization studies (finding norms for a population) have taken place in many non-Western countries mainly using the DDST in a translated and occasionally adapted form<sup>16-18</sup>, but none of these in Africa. Only two studies have attempted standardisation in Africa. One using a translated form of the Bayley scales with an urban black South African population<sup>19</sup> and the other on a limited age range in a rural Nigerian population<sup>20</sup>.

It is clear that Western developmental assessment tools may include tasks and materials, which are completely alien to other cultures. These tools may therefore fail to identify and assess children adequately in cultural settings other than those for which they were created<sup>21</sup>. This may be less of a problem when comparing groups of children but when Western tools are used alone as an outcome measure, culture may have an effect. In theoretical studies, culture has been demonstrated to have an influence on child development, particularly in the area of social development<sup>22-24</sup>. Cognitive abilities such as memory, categorization techniques and pattern recognition have also been known to be influenced by culture<sup>25-28</sup>. Even gross motor development, may possibly be affected by culture<sup>29-31</sup>.

In this study, we aimed to create a simple, culturally appropriate developmental assessment tool adapted and modified from Western tools but also standardized for use in rural Malawi. The first stage in the development of this tool was to identify

which items from Western tools (e.g. the DDST or Denver II) were not relevant to the age appropriate experiences of rural Malawian children. These items were then replaced with ones more appropriate to this cultural context. We did this by firstly holding focus groups to agree which items should be replaced and to create alternative items. All items (both retained and new) were then validated and standardized in a large population study. The performance of all items was examined in a consensus meeting and a revised instrument proposed.

## **METHODS:**

### **Setting and study population:**

This study was a sub-study of the Lungwena Child Survival Study (LCSS), a prospective family cohort study looking at gestational health and the growth, development, morbidity and mortality of rural Malawian infants and children. Lungwena is an area in southern Malawi where a government health centre serves an approximately 100km<sup>2</sup> rural area with some 17,000 people in 23 villages. Most of the inhabitants are Muslims of the Yao tribe. The literacy rate is low and subsistence farming and fishing form the main occupations. The original cohort for the LCSS study was enrolled between June 1995 and August 1996. All pregnant women presenting for antenatal care were eligible for the LCSS study and 97% of the population of pregnant women in the area, at that time, were enrolled in the study. Details of recruitment, collection of background data and follow up has been described previously<sup>32,33</sup>.

The population of children used for this study is the original LCSS cohort children aged between 3.5 to 6.5 years and younger siblings aged 0 to 3.5 years. Out of the 1237 LCSS and siblings available, 1197 were seen with 40 families either refusing to take part, or not being available. Ages of children were known from LCSS birth data or from the “health passport” given to mothers at the birth of their baby where the date of birth is recorded and which almost all mothers carry with them for all health appointments. A quota sampling strategy was used as in the DDST and Denver II<sup>34</sup> with target numbers of children being sought in each of 33 age groups (see supplement table A). 67 children were excluded due to premature birth (34 weeks or less measured by fundal height at antenatal clinic)<sup>32</sup>, twin birth, or significant disability including severe malnutrition (weight for height Z score of less than -2) leaving 1130 children in the final analysis.

The Lungwena Child Survival Study received approval from the National Health Science Research Committee in Malawi (HSRC 93/94). Informed verbal consent was sought from each mother at the beginning of the LCSS study, and again before a development assessment was carried out.

### **Creation of the developmental assessment tool:**

The Denver II, DDST and Griffith’s were examined by the Malawian research team. Items considered to be “culturally appropriate” were included and translated whereas

those considered “inappropriate” such as, “prepares cereal” or “plays board/card games” were removed. New items and modifications to Western test items were then created through a series of focus groups. Key informants were the eight local research workers. They were all women of child-bearing age with at least eight year’s education and research experience of at least five years. Themes relating to developmental milestones were discussed and ideas from these sessions were used to create new items. Illustrations were made for most items in the instrument, and used as prompts for the research workers. Some came with permission from “Disabled Village Children”<sup>35</sup>.

Face validity<sup>36</sup> and content validity were assessed by all research assistants, five Malawian paediatricians, a language expert from the University of Malawi and six medical students at the College of Medicine (C.O.M), Malawi. Once the new instrument was created, the team was trained in its use and it was piloted in two stages. At each stage, feedback and training were given and problematic items were re-adapted or re-translated. The process of creating and refining the more culturally appropriate tool is shown in figure 1.

#### **Standardisation using a normal population sample:**

1197 children were assessed on one occasion between February 2000 and April 2001 on a home visit by research assistants. The assessment took approximately 35 minutes to complete and where possible, items were directly observed. In a few cases a report was given, for example “does he go to the toilet by himself?”. Items were scored as either pass or fail, or “don’t know” if the child was uncooperative or unwell. Items were asked until the child failed 7 items in a row.

Data entry and analysis was done using Microsoft Excel 6.0, SPSS 11.1, Stats-direct and STATA computer programs. Each child in the study was identified by a code. Data were checked prior to analysis and any outlying results were reviewed.

Standardization is the process of determining normal age ranges for which children pass the items for a developmental assessment tool. A logistic regression analysis was carried out with decimal age and sex as explanatory variables. The observed and predicted probability of passing was determined and graphs were drawn for each item. The goodness of fit of the graph was visually assessed and discrepancies reviewed. To determine statistically whether or not the fitted curve was a sufficiently good representation of the data, a “goodness of fit” statistic was calculated.<sup>37</sup> If this was significant at the 5% level, indicating a poor fit, then the data were re-examined and refitting was done using triple split spline regression. The ages corresponding to the 35<sup>th</sup> and 65<sup>th</sup> percentiles were calculated from the original fit to determine the cut-points. For some items that performed less well, the cut-points were chosen by viewing the graphs to facilitate a good fit. Three logistic curves were then fitted, one for each region, based on the split.<sup>38:39</sup> Any items with significant gender effects were removed or considered for further modification to ensure the tool was applicable to all children irrespective of gender. Using the predicted probabilities found from the logistic regression analyses, the ages corresponding to 25%, 50%, 75% and 90%

percent of the children passing were determined for each item. These were then used to plot the age norms of achievement of each milestone in a box-type representation.

### **Reliability of the items:**

Reliability for each item was tested by using two sub-samples of 60 (interobserver) and 28 (intraobserver) randomly selected children who were seen at 7 and 14 days. 46 of the 60 children completed the follow up using two different examiners (interobserver) and 25 of the 28 children using the same examiner (intraobserver). All items in the tool were assessed for both types of reliability. Kappa statistics (k) with 95% confidence intervals (CI) were used to calculate the degree of observer agreement for each question. Positive values of 0 to <0.2 indicate poor agreement, >0.2 to 0.4 fair agreement, >0.4 to 0.6 moderate agreement, >0.6 to 0.8 good and >0.8 to 1 very good agreement<sup>40</sup>.

Respondent validation was carried out after the preliminary analysis. This method of validation involves the reporting of findings back to the participants. Findings were fed back at the end of the study to the Lungwena Health Centre Management Committee. This consisted of four chiefs, one overall representative and three women representatives, all from the local area.

### **Consensus meeting:**

Once all the items were analyzed, an expert panel which included a Malawian paediatrician (MG, AJ, EM, and GL) met to review the results and decide which items should remain, which be modified and which removed. Items were judged on their graphical representation, and “goodness of fit” on logistic regression, reliability and subjective ratings of “interpretability” by participants and researchers.

## **RESULTS:**

A tool with 138 items, 34 gross motor (GM), 34 fine motor (FM), 35 language and 35 social items was created. An example of the tool is shown in supplement figure B. The majority (58%) of items were from the DDST and Denver II, with a small percentage (9%) from the Griffith's. Many items in the GM (82%) language (77%) and FM (70%) sections were directly translated from western tests with modifications mainly in the FM section. Only 37% of the social items were taken from western tests. The first two columns of table 1 provide examples of many of the items that were removed from the DDST or Denver II, and shows the newly created items which replaced them.

**Table 1: Examples of specific items added or removed during process of creating new more culturally appropriate tool.**

Domain of development	DDST or Denver II items removed at Stage 1:	New items replaced at Stage 1:	DenverII/Griffith's items removed or needing modification after consensus meeting	New items removed or needing modification after consensus meeting.
Gross motor	<ol style="list-style-type: none"> <li>1. Head up to 45 degrees</li> <li>2. Walk up steps</li> <li>3. Pedals trike</li> </ol>	<ol style="list-style-type: none"> <li>1. Dances to music</li> <li>2. Kneels well to be respectful</li> <li>3. Climbs and gets down</li> <li>4. Carries object on head with one hand</li> <li>5. Pushes wheel with stick</li> <li>6. Carries water on head – no hands</li> </ol>	<ol style="list-style-type: none"> <li>1. Pulls self to stand (not understood by research assistants)</li> <li>2. Touches toes with legs straight (difficult to teach)</li> </ol>	<ol style="list-style-type: none"> <li>1. Dances (not specific enough)</li> <li>2. Carries object on head with one hand. (need to specify exact object)</li> <li>3. Carries water on head with no hands (need to specify size)</li> </ol>
Fine motor	<ol style="list-style-type: none"> <li>1. Look for yarn</li> <li>2. Thumb wiggle</li> <li>3. Thumb finger grasp</li> </ol>	<ol style="list-style-type: none"> <li>1. Bangs drum/pot</li> <li>2. Moulds ball with clay</li> <li>3. Makes doll of clay</li> <li>4. Sorts objects into groups</li> <li>5. Picks longest stick</li> </ol>	<ol style="list-style-type: none"> <li>1. Draws a person 3 parts (many not passing by 6 years)</li> <li>2. Draws a person 6 parts (many not passing by 6 years)</li> </ol>	<ol style="list-style-type: none"> <li>1. Moulds ball with clay (task not normally done by children)</li> <li>2. Bangs drum/pot (translation “plays drum” incorrect)</li> <li>3. Builds house of corn cobs (sex specific)</li> </ol>
Language	<ol style="list-style-type: none"> <li>1. Responds to bell</li> <li>2. Squeals</li> <li>3. Point to pictures/name pictures</li> <li>4. Count 1 block</li> <li>5. Uses plurals</li> </ol>	<ol style="list-style-type: none"> <li>1. Sings</li> <li>2. Knows today and tomorrow</li> <li>3. Knows name of own village.</li> <li>4. Uses respectful terms</li> <li>5. Knows father's name</li> <li>6. Can count bottle tops to 10</li> </ol>	<ol style="list-style-type: none"> <li>1. Knows 3 colors (colours used differently in Malawi)</li> <li>2. Knows opposites (not specific enough-question needed clarifying)</li> </ol>	<ol style="list-style-type: none"> <li>1. Uses respectful terms (poor reliability)</li> <li>2. Knows father's name (poor reliability)</li> <li>3. Can count bottle tops to 10 (counting learned at school-not many children in school/nursery &lt;5)</li> </ol>
Social	<ol style="list-style-type: none"> <li>1. Play pat-a-cake</li> <li>2. Play ball w/examiner</li> <li>3. Resists toy pull</li> <li>4. Plays peek-a-boo</li> <li>6. Use</li> </ol>	<ol style="list-style-type: none"> <li>1. Shares things</li> <li>2. Plays with friends</li> <li>3. Spends most of time on mum's back</li> <li>4. Eats with family in a group</li> <li>5. Can plant seeds by self</li> <li>6. Washes dishes</li> </ol>	<ol style="list-style-type: none"> <li>1. Helps in house</li> <li>2. Put on clothing with help (poor reliability)</li> <li>3. Feeds self (specify what type of food)</li> <li>4. Drinks from cup by self (not specific)</li> </ol>	<ol style="list-style-type: none"> <li>1. Spends most of time on mum's back (family dependent)</li> <li>2. Shy with strangers (poor reliability)</li> <li>3. Sweeps (sex specific)</li> <li>4. Washes dishes (sex specific)</li> <li>5. Goes to the toilet</li> </ol>

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spoon/fork	7. Washes clothes	enough regarding	with help (not specific
7. Feed doll	8. Sweeps	how well or not	enough e.g. Older
8. Brush teeth	9. Goes to the toilet	child needed to do	children need help
with help	with help	this )	using pit latrines)
9. Name friend	10. Goes to the toilet		
10. Play board	by self		
games	11. Makes porridge		
12. Prepare	by self		
cereal	12. Adds wood to fire		
13. Plays	13. Can build fire by		
interactive	self		
games e.g. Tag			
14. Buttons up			

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Face validity and content validity of the tool was tested. The modified instrument appeared to those questioned, to cover development in children in ways that were important and was judged to examine in a fully comprehensive and logical fashion, the domains of child development for children in Malawi. It was therefore considered to have good face validity and content validity. The majority of items were found acceptable for studying children's development in this setting through, respondent validity. The pictures as prompts were found to be particularly helpful to the researchers in the field.

Examples of graphs created through logistic regression during the standardization procedure and where triple split joined regression was used, are shown in Figure 2. In terms of goodness of fit on logistic regression and on spline regression, social items 51% (18/35) had the highest number of poor fits, sex being an independent predictor in some of these 23% (8/35) (see table 2). A larger proportion of the newly created items had a poor fit on logistic regression (15% (7/46)) and an effect of sex (17% (8/46)) than those from the Western tools. The few items not attained by 6 years came from the fine motor area of development and included "draws a man with 6 parts" and "draws a square". The results of the Lungwena milestones for the language section of development are shown in Figure 3. The other areas of development can be found in Supplement figure C.

Reliability results are also shown in Table 2.

**Table 2: Decisions regarding suitability of items within (i) each domain of development and (ii) source of question**

	Domain of development				Source of question			Total
	GM	FM	Lan g	Soci al	Den ver or DDST	Griffith 's	Newly deri ved	
No. of items in total	34	34	35	35	80	12	46	138
Inter-observer items with kappa >0.4	29	28	30	26	72	8	33	113
Intra-observer items with kappa >0.4	32	29	24	21	68	9	29	106
Poor fit on logistic regression	1	0	3	9	6	0	7	13
Sex effect on logistic regression	0	3	0	8	3	0	8	11
Not attained by 6 years	0	4	0	0	4	0	0	4
Poor interpretability or translation	1	2	9	9	7	4	10	21
To be included or modified for revised version of the tool	33	27	32	18	69	9	32	110

For inter-observer reliability 82% (113/138) of the questions had moderate to very good reliability ( $K > 0.4$ ). There are no figures in the Denver technical manual for inter-observer reliability for comparison. Intra-observer reliability demonstrated moderate to very good reliability ( $K > 0.4$ ) for 75% (106/138) of the questions. This compares well with Denver II figures<sup>34</sup> where 81% of their items had a kappa  $> 0.4$ . In relation to the domains of development, GM items had the best overall inter-observer (29/34 items) and intra-observer (32/34 items) reliability with kappa  $> 0.4$ . Items from the social area performed less well with only 74% (26/35) of the items on inter-observer reliability and 60% (21/35) of the intra-observer items having a kappa  $> 0.4$ . In relation to the source of the item, more of the locally-derived items had poor inter-observer (33/46) and intra-observer (15/46) reliability (kappa  $< 0.4$ ) in comparison to those items derived from the Denver II (12/80 and 8/80).

After consensus meeting, 110 of the 138 items (80%) were retained in the revised instrument, with some needing further modification. Only 69% (32/46) of the newly created items were retained in comparison to 86% (69/80) of the DDST or Denver items used (see Table 2). The results of this meeting giving examples of items removed are detailed in the last two columns of table 1.

## DISCUSSION:

We have demonstrated that many items from Western tools can work well when adapted and translated for other settings. They have already had their own rigorous reliability and validity studies carried out in the West and therefore are more likely to be robust in their use. However, through our focus group, validation and piloting work, we have also demonstrated that in all domains of Western tests (such as the DDST), there are some items which are culturally inappropriate for a rural African population. For example, questions such as “prepares cereal” or “plays board games/card games” are uncommon things for children in rural Africa. Also, the pink doll in the DDST kit was terrifying to most children when used in piloting. Many children had never seen anything like it and many screamed. It would have been unlikely that we would have been able to get them to sit down and “feed the doll”. Some of the naming questions in the Language section of the DDST or Denver II have pictures of objects that children, at least in the part of rural Africa studied, have never seen before, such as a horse and a car. This makes it difficult for them to name them, especially as many children have also never seen a book at their age, or pictorial representations of many objects.

In the creation of new items however, many newly created items were less reliable, more sex-specific and had poorer goodness of fit in logistic regression. This was most evident in the social domain and least evident for gross motor skills. Social skills seem to have the least “universality” and in measuring them, we need to question the appropriateness of the concepts being measured in such different settings. When measuring “social skills” we may be determining the ability of the child to have learned important skills instilled by parents and carers in particular cultural settings, but this can only be measured if pertinent skills are tested for. The difficulty when creating new social items for a tool such as this one, is that the items must be specific enough to determine between the developmental age ranges of children, but also clear and easy to explain in a developmental tool. This will continue to be a challenge.

It was not a primary aim of our study to compare our results with the Denver II or DDST. A formal statistical comparison has not been possible, however, when comparing our charts with those from the Denver II or DDST on gross comparison, it does seem that there are obvious differences in milestones with children from the West. For example, the item “combines two words” in the Denver II is attained at the age of between 17 and 21 months, whereas in our sample this was obtained at between 21 months and 2 years 4 months. This demonstrates the importance and necessity of creating norms for a given African population, as they are likely to be different to those from the West.

A second phase of work is currently underway using the methodology that we have formulated in this first study to refine a further tool with a larger standardization sample. This work will include creating a scoring system, doing more detailed reliability measurements and further validity tests of between-group and construct validity. Once this new version has been created and has gone through the strict procedures that we have instituted in our methodology, we hope to have created a tool that may benefit community health workers in other rural settings in Africa after local validation. The complete tool may also be used by research workers who are looking at developmental outcomes as part of their intervention strategies.

**Figure 1:** Process of creation of a more culturally appropriate developmental assessment tool.

**Figure 2:** Examples of (a) good logistic fit for fine motor question 8 'Transfers objects from hand to hand' (b) spline fit for gross motor question 17 'Walks backwards' (c) poorly worded question - social question 16 'Can put clothes on with help'.

**Figure 3** Example of developmental milestones achieved by Lungwena children in the area of language development. Age ranges given for percentage of children passing an item.

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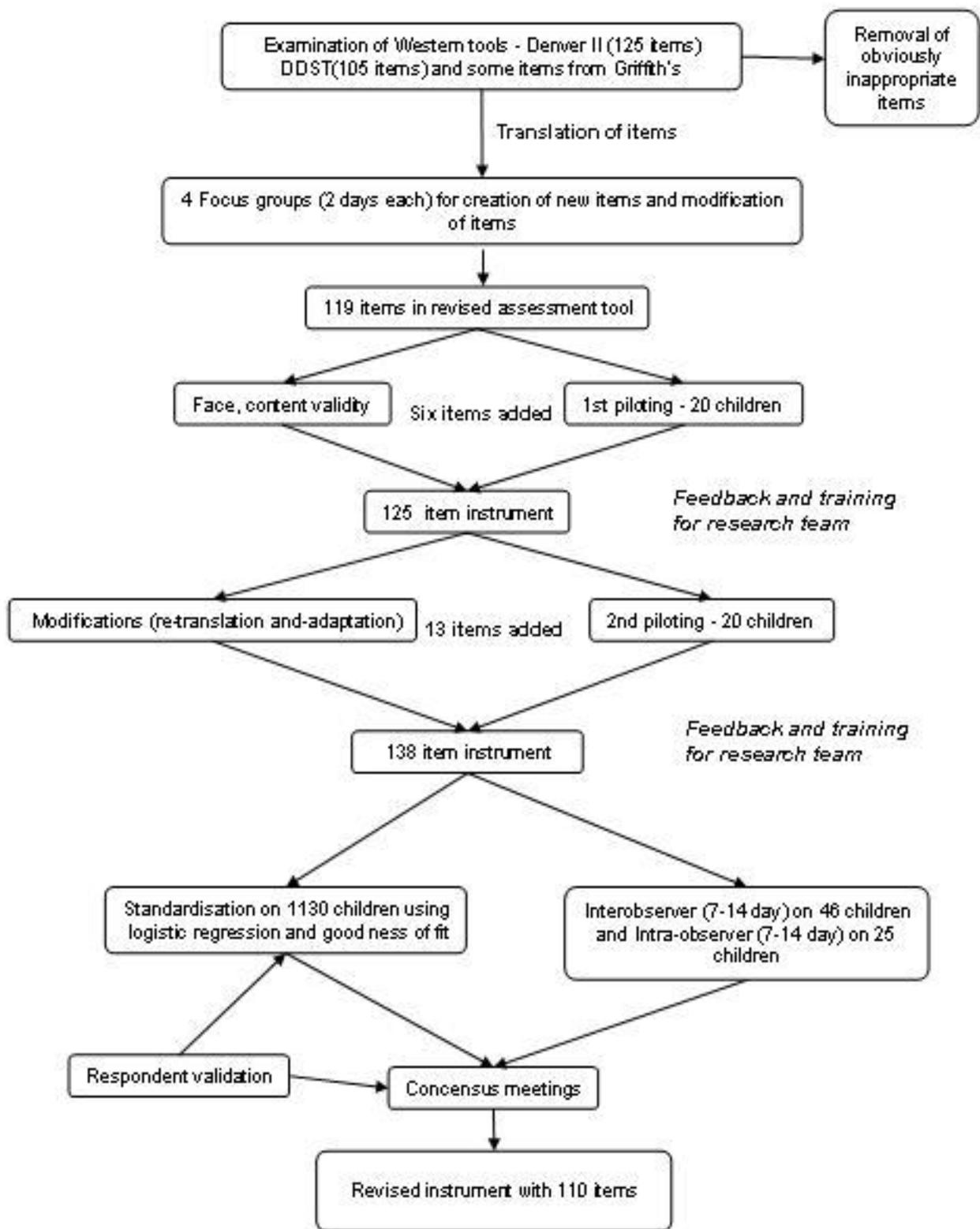
### Reference List

- (1) World Health Organization (W.H.O) Disability and Rehabilitation Team pA58/17 (site updated Dec 2003). Disability, including prevention, management and rehabilitation. Report by the secretariat. <http://www.who.int/nmh/a5817> . 2005.  
Ref Type: Internet Communication
- (2) Committee on Children with Disabilities. Developmental Surveillance and Screening of Infants and Young Children. *Pediatrics* 108, 192-195. 2001.  
Ref Type: Journal (Full)
- (3) Durkin MS, Davidson LL, Desai P, et al. Validity of the ten-question screen for childhood disability: results from population based studies in Bangladesh, Jamaica and Pakistan. *Epidemiology* 5, 283-289. 2005.  
Ref Type: Journal (Full)
- (4) Powell CA, Walker S.P., Himes J.H., Fletcher P.D., Grantham-McGregor S. Relationships between physical growth, mental development and nutritional supplementation in stunted children: the Jamaica study. *Acta Paediatrica* 84, 22-29. 1995.  
Ref Type: Journal (Full)
- (5) Joos SK., Pollitt E., Mueller WH., et al. The Bacon Chow Study: Maternal nutritional supplementation and infant behavioural development. *Child Dev.* 54, 669. 1983.  
Ref Type: Journal (Full)
- (6) Bayley N. Bayley Scales of Infant Development manual. 2nd edition ed. San Antonia: Harcourt Brace and Company.; 1993.
- (7) Griffiths R. *The Abilities of Young Children*. ARICD, Amersham.; 1984.
- (8) McCarthy D. McCarthy Scales of Children's Abilities. New York: The Psychological Corporation; 1972.
- (9) Frankenburg WK, Dodds J, Archer P, Shapiro H, Bresnick B. The Denver II: a major revision and restandardization of the Denver Developmental Screening Test. *Pediatrics* 1992; 89(1):91-97.
- (10) Boivin MJ, Green SD, Davies AG, Giordani B, Mokili JK, Cutting WA. A preliminary evaluation of the cognitive and motor effects of pediatric HIV infection in Zairian children. *Health Psychol* 1995; 14(1):13-21.
- (11) Boivin MJ, Giordani B, Ndanga K., Maky MM, Manzeki KM, Ngunu N et al. Effects of Treatment for Intestinal Parasites and Malaria on the

- Cognitive Abilities of Schoolchildren in Zaire, Africa. *Health Psychol* 1993; 12(3):220-226.**
- (12) **Geisinger K. Cross-cultural Normative Assessment: Translation and Adaptation Issues Influencing the Normative Interpretation of Assessment Instruments. *Psychological Assessment* 6[4], 304-312. 2006.  
Ref Type: Journal (Full)**
  - (13) **Drotar D, Olness K, Wiznitzer M, Schatschneider C, Marum L, Guay L et al. Neurodevelopmental outcomes of Ugandan infants with HIV infection. An application of growth curve analysis. *Health Psychol.* 18[2], 114-121. 1999.  
Ref Type: Journal (Full)**
  - (14) **Stoltzfus RJ, Kvalsvig JD, Chawaya HM, Montresor A, Albonico M, Tielsch JM et al. Effects of iron supplementation and antihelminthic treatment on motor and language development of preschool children in Zanzibar: double blind, placebo controlled study. *British Medical Journal* 323, 1389-1393. 2001.  
Ref Type: Journal (Full)**
  - (15)  **Holding PA, Taylor HG, Kazungu SD, Mkala T, Gona J, Mwamiye B et al. Assessing cognitive outcomes in a rural African population: development of a neuropsychological battery in Kilifi District, Kenya. *Journal of the International Neuropsychological Society* 10[2], 246-260. 2004.  
Ref Type: Journal (Full)**
  - (16) **Al-Naquib N, Frankenburg WK, Mirza H, Yazdi AW, Al-Noori S. The standardization of the Denver Developmental Screening Test on Arab children from the Middle East and north Africa. *J Med Liban* 1999; 47(2):95-106.**
  - (17) **Lim HC, Chan T, Yoong T. Standardisation and adaptation of the Denver Developmental Screening Test (DDST) and Denver II for use in Singapore children. *Singapore Med J* 1994; 35(2):156-160.**
  - (18) **Song J, Zhu YM, Gu XY. Restandardization of Denver Developmental Screening Test for Shanghai children. *Chin Med J (Engl )* 1982; 95(5):375-380.**
  - (19) **Richter LM, Griesel R, Rose C. The Bayley Scales of Infant Development: A South African standardization. *South African Journal of Occupational Therapy* 22[1], 14-25. 1992.  
Ref Type: Journal (Full)**
  - (20) **Ogunnaike OA, Houser RFJ. Yoruba toddlers' engagement in errands and cognitive performance on the Yoruba Mental Subscale. *International***

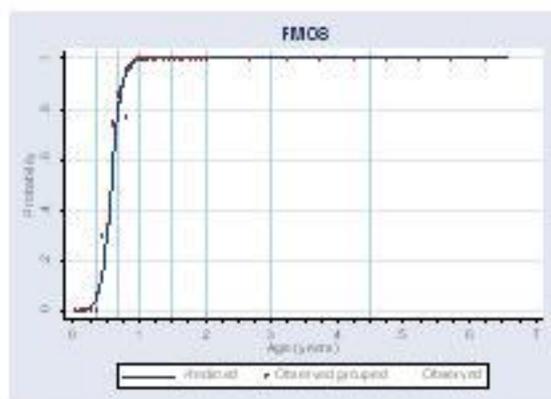
- Journal of Behavioural Development. 26[2], 145-153. 2002.**  
**Ref Type: Journal (Full)**
- (21) **Olade RA. Evaluation of the Denver Developmental Screening Test as applied to African children. Nurs Res 1984; 33(4):204-207.**
  - (22) **Levine RA, Dixon S, Levine S, Richman A, Leiderman PH, Keefer CH et al. *Child care and Culture: Lessons from Africa*. Cambridge: Cambridge University Press; 1994.**
  - (23) **Whiting B&WJ. *Children of six cultures. A psycho-cultural analysis*. Harvard, Mass.: Harvard University Press.; 1975.**
  - (24) **Kambalmetore S, Hartley S, Lansdown R. An exploration of the Malawian perspective on children's everyday skills: implications for assessment. Disability and Rehabilitation, 2000; 22(17):802-807.**
  - (25) **Serpell R. How specific are perceptual skills? A cross-cultural study of pattern reproduction. British Journal of Psychology 1979; 70:365-380.**
  - (26) **Rogoff B, Waddell KJ. Memory for information organized in a scene by children from two cultures. Child Development 53, 1224-1228. 1982.**  
**Ref Type: Journal (Full)**
  - (27) **Curran HV. *Nigerian Children: Developmental Perspectives*. London, Boston, Melbourne and Henley: Routledge & Kegan Paul; 1984.**
  - (28) **Glick J. Cognitive development in cross-cultural perspective. In: F.Horowitz et al., editor. *Review of child development research*. Chicago.: University of Chicago Press.; 1975.**
  - (29) **Super CM. Environmental Effects on Motor Development: the Case of "African Infant Precocity". Developmental Medicine and Child Neurology 1976; 18:561-567.**
  - (30) **Warren N. African infant precocity. Psychological Bulletin 1972; 78:353.**
  - (31) **Geber M. Developpement psycho-moteur de l'enfant africain. Courier 1956; 6:17.**
  - (32) **Vaahtera M, Kulmala T, Ndeka M, Koivisto A-M, Cullinan T, Salin M-J et al. Ante and perinatal predictors of infant mortality in rural Malawi. Archives of Diseases in Childhood Fetal and Neonatal Edition 2000; 82:F200-F204.**
  - (33) **Maleta K, Virtanen S, Espo M, Kumala T, Ashorn P. Timing of growth faltering in rural Malawi. Archives of Diseases of Childhood 2003; 88:574-578.**

- (34) Frankenburg WK, Dodds JB, Archer P, Shapiro H, Bresnick B. **Denver II Technical Manual**. Denver, Colorado: Denver Developmental Materials Inc; 1990.
- (35) Werner D. *Disabled Village Children - A guide for community health workers, rehabilitation workers, and families*. Berkeley, California.: The Hesperian Foundation; 1987.
- (36) Eiser C, Morse R. **Quality of life measures in chronic diseases of childhood**. *Health Technology Assessment* 2001; 5(4).
- (37) Lemeshow S, Hosmer D. **A review of Goodness of Fit Statistics for use in the Development of Logistic Regression Models**. *American Journal of Epidemiology* 115[1], 92-106. 1982.  
Ref Type: Journal (Full)
- (38) Greenland S. **Dose-Response and Trend Analysis in Epidemiology: Alternatives to Categorical Analysis**. *Epidemiology* 1995; 6(4):356-364.
- (39) Pastor R, Guallar E. **Use of Two-segmented Logistic Regression to Estimate Change-points in Epidemiological Studies**. *American Journal of Epidemiology* 148[7], 631-642. 1998.  
Ref Type: Journal (Full)
- (40) Landis R, Koch G. **The measurement of observer agreement for categorical data**. *Biometrics* 33, 159-174. 1977.  
Ref Type: Journal (Full)



**Figure 1:** Process of creation of more culturally appropriate developmental assessment tool

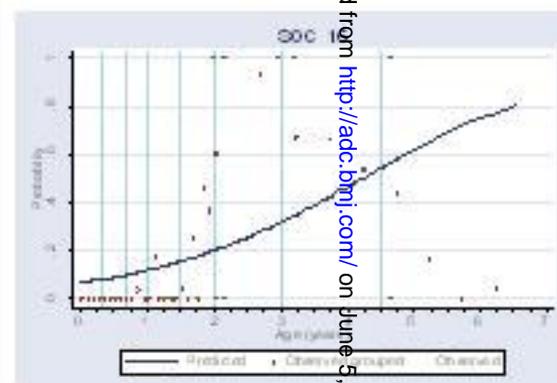
**Figure 2:** Examples of (a) good logistic fit for fine motor question 8 'Transfers objects from hand to hand' (b) spline fit for gross motor question 17 'Walks backwards' (c) poorly worded question - social question 16 'Can put clothes on with help'.



**(a)**

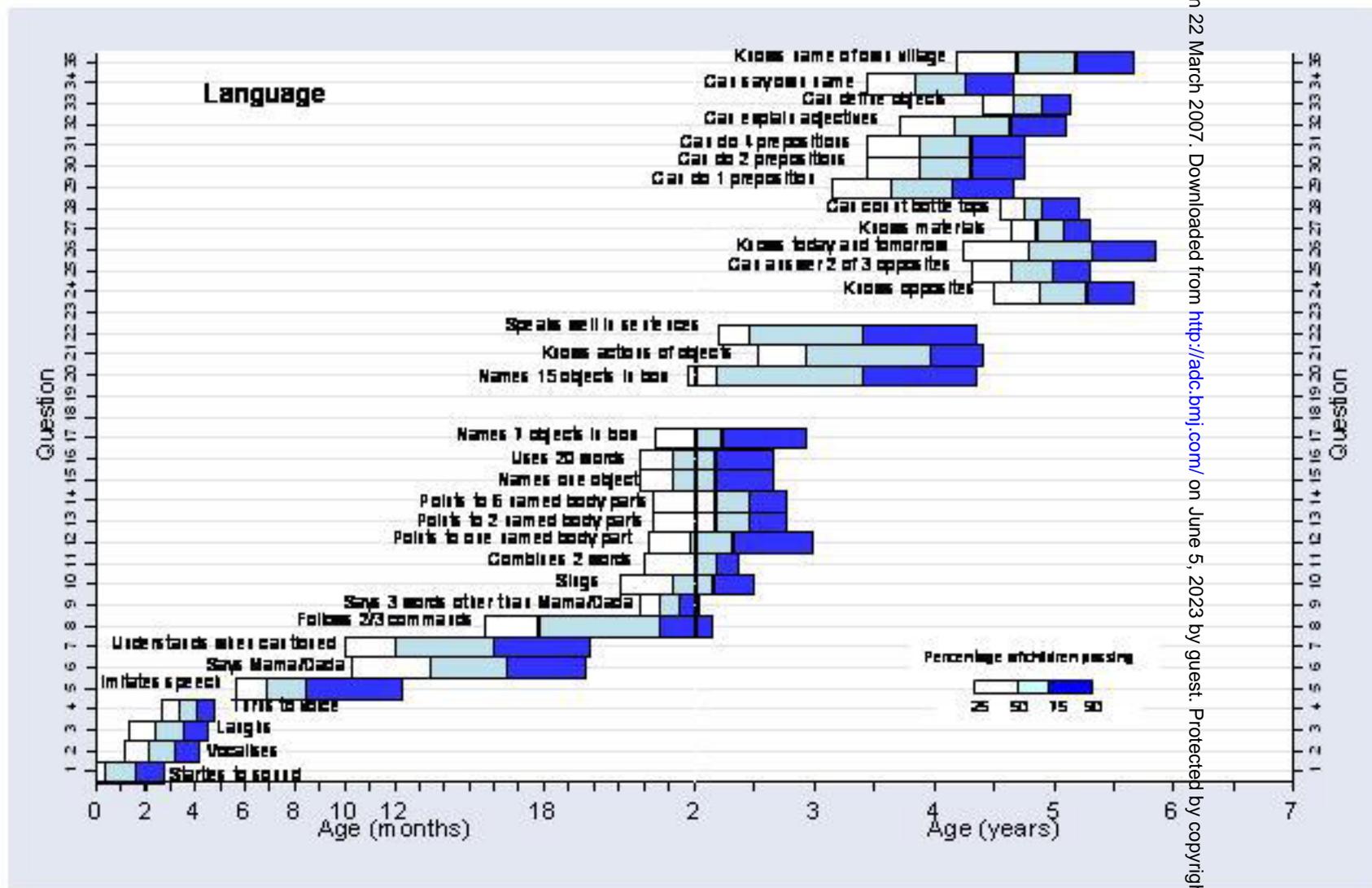


**(b)**



**(c)**

**Figure 3** Example of developmental milestones achieved by Lungwena children in the area of language development. Age ranges given for percentage of children passing an item.



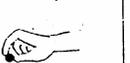
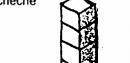
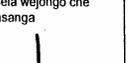
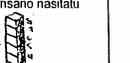
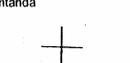
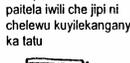
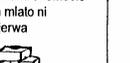
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**Supplement Table A: Distribution of sample by age:**

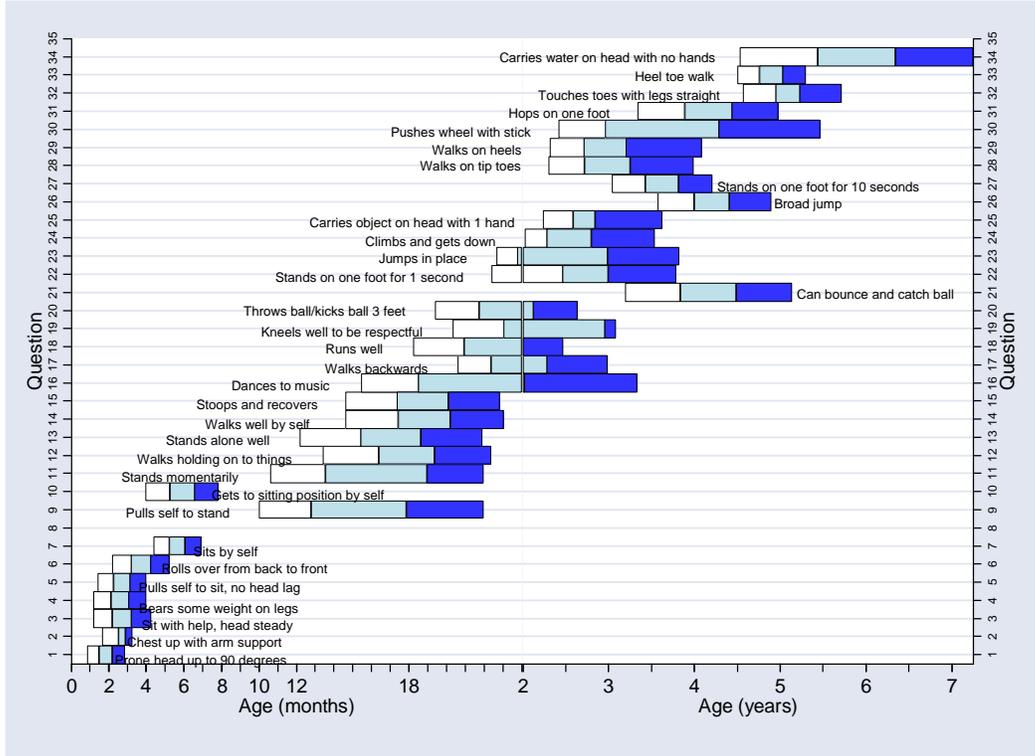
Age group	Age in months (yrs)	Mid-point decimal age	No of children
1	0-1	0.04	7
2	1-2	0.125	37
3	2-3	0.208	21
4	3-4	0.292	31
5	4-5	0.375	35
6	5-6	0.458	37
7	6-7	0.542	35
8	7-8	0.625	31
9	8-9	0.708	36
10	9-10	0.792	31
11	10-11	0.875	28
12	11-12	0.988	30
13	12-13	1.042	26
14	13-14	1.125	23
15	14-15	1.208	13
16	15-16	1.292	30
17	16-17	1.375	21
18	17-18	1.458	13
19	18-19	1.542	26
20	19-20	1.625	13
21	20-21	1.708	12
22	21-22	1.792	13
23	22-23	1.875	13
24	23-24	1.958	11
25	24-30 (2-2 ½ )	2.042	50
26	30-36 (2 ½-3)	2.708	30
27	36-42 (3-3 ½ )	3.25	71
28	42-48 (3 ½ -4)	3.75	114
29	48-54 (4- 4 ½ )	4.25	124
30	54-60 (4 ½ -5)	4.75	95
31	60-66 (5- 5 ½ )	5.25	46
32	66-72 (5 ½ - 6)	5.75	1
33	72-78 (6- 6 ½ )	6.25	26
Total number of children			1197

**Supplement Figure B: Example of instrument:**

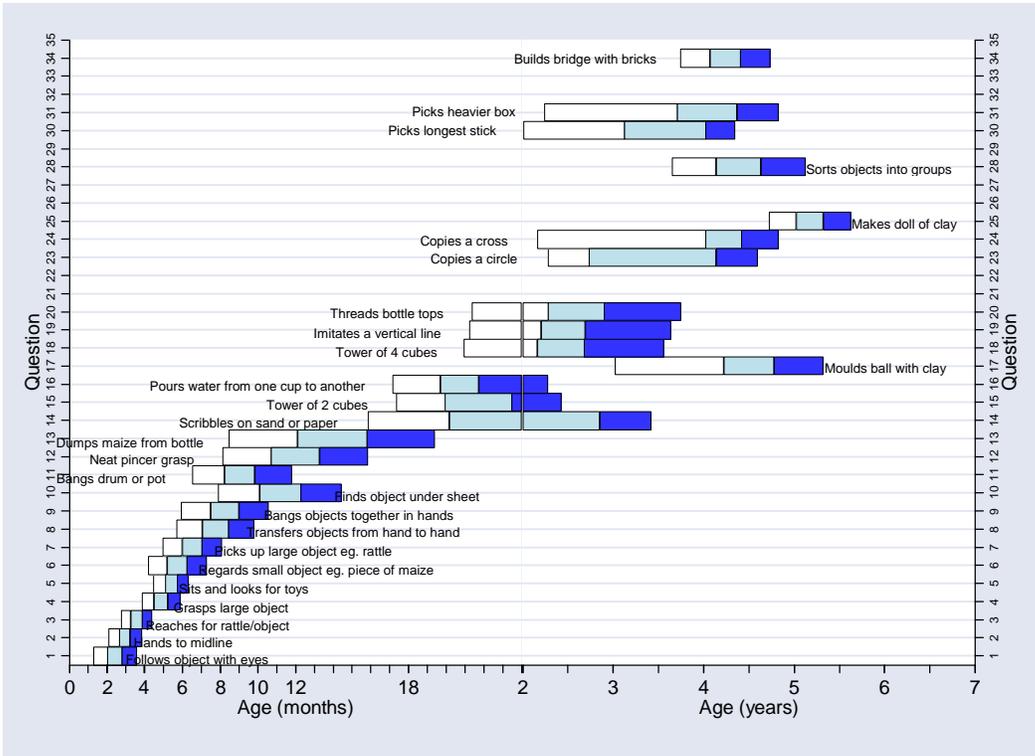
**FINE MOTOR:**

<p>1. Kuya chindu nineso</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>2. Kuwika makono pampepe</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>3. Mpana alinje kamula chindu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>4. Kamula mwamachili</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>5. Mpakana alame niku lola chang'andila</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>6. Mpaka ayiwone yindu yanwana mpela mitesa</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>7. Mpakana aioko te chindu chekulungwa</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>
<p>8. Chakamwile wanchiji mpakana awiche nkono walyo</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>9. Kwala nyala ali ni chindu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>10. Mpakana asose chindu chamwasitile mpala chidole/changandila</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>11. Kugomba ng'oma</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>12. Akusa lokota yindu ya wana wana ni yala</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>13. Mpakana ajase imanga yewiche mwi botolo</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>14. Akulembaga pasi</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>
<p>15. Mpakana asajikane njelwa siwili-pakana syasye</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>16. Kwanganya yindu muma kapo gawili</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>17. Akusagumba mpila</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>18. Mpakana asajikanye mcheche</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>19. Mpakana alembe musela wejongo che munsanga</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>20. Mpakana atunje yuma ni singano</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>21. Mpakana asajikanye njelwa nsano nastatu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>
<p>22. Kupanganya nyumba niyisonde</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>23. Mpakana alembe zilo</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>24. Mpakana alembe mtanda</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>25. Akusagumba mundu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>26. Mpakana ajambule libokosi la folo kona</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>27. Mpakana ajambule mundu mwakuwonechela</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>28. Kusagua inu mmagulu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>
<p>29. Kupanganya yang'andira mpela galimoto</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>30. Mpakana ako mbole paitela iwili che jipi ni chelewu kuyilekanganya ka tatu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>31. Mpakana akombole kulekanganya libokosi yawusito ni iyakupepuka ka tatu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>32. Alembe mundu ni jwalo nsanu na chimo</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>33. Mpakana akombole kulekanganya mitundu</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>34. Mpakana akombole kutawa milato ni idina/njerwa</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>	<p>34. Mpakana akombole kutawa milato ni idina/njerwa</p>  <p>Yelo <input type="checkbox"/> Iyai <input type="checkbox"/> Ngingu- <input type="checkbox"/></p>

**Supp figure C: Age ranges for percentage passing items by area of development.**  
 (a) Gross Motor



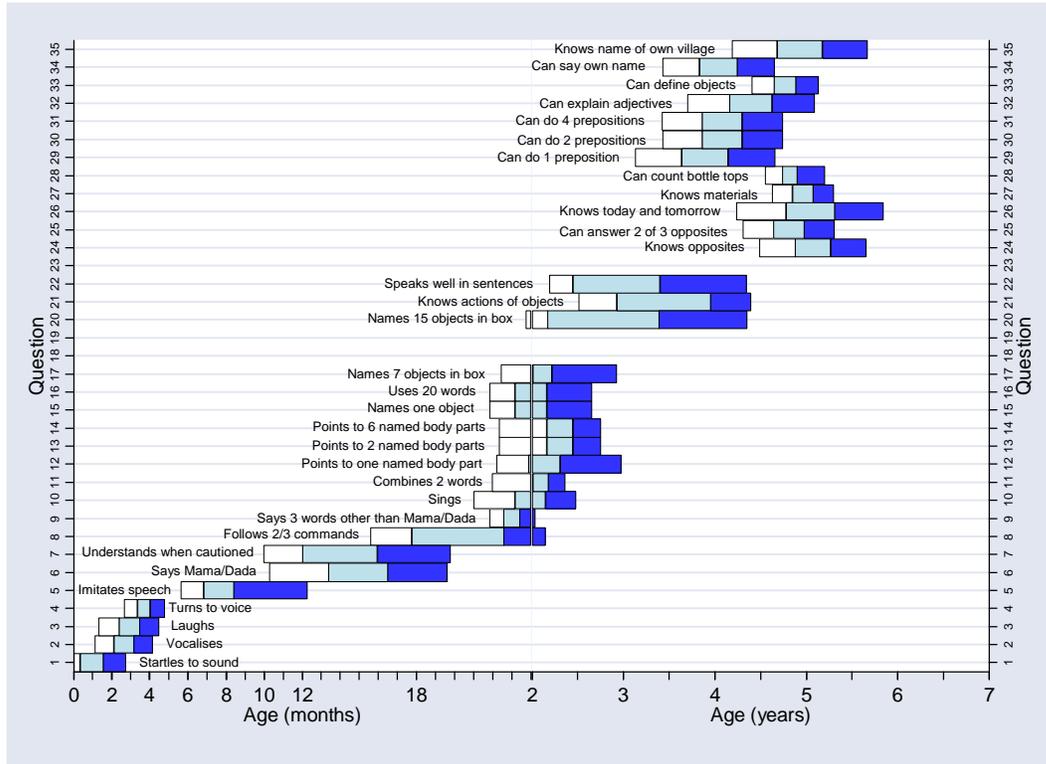
(b) Fine Motor



Percentage of children passing



(c) Language



(d) Social

