ABILHAND-Kids

A measure of manual ability in children with cerebral palsy

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Abstract—*Objective:* To develop a clinical tool for measuring manual ability (ABILHAND-Kids) in children with cerebral palsy (CP) using the Rasch measurement model. *Methods:* The authors developed a 74-item questionnaire based on existing scales and experts' advice. The questionnaire was submitted to 113 children with CP (59% boys; mean age, 10 years) without major intellectual deficits (IQ $>$ 60) and to their parents, and resubmitted to both groups after 1 month. The children's and parents' responses were analyzed separately with the WINSTEPS Rasch software to select items presenting an ordered rating scale, sharing the same discrimination, and fitting a unidimensional scale. *Results:* The final ABILHAND-Kids scale consisted of 21 mostly bimanual items rated by the parents. The parents reported a finer perception of their children's ability than the children themselves, leading to a wider range of measurement, a higher reliability (R = 0.94), and a good reproducibility over time (R = 0.91). The item difficulty hierarchy was consistent between the parents and the experts. The ABILHAND-kids measures are significantly related to school education, type of CP, and gross motor function. *Conclusions:* ABILHAND-Kids is a functional scale specifically developed to measure manual ability in children with CP providing guidelines for goal setting in treatment planning. Its range and measurement precision are appropriate for clinical practice.

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Cerebral palsy (CP) is the most common cause of physical disability in children.[1] While the rates of perinatal and infant mortality have declined toward the end of the last century,[2] the rate of CP has remained at 2 to 2.5 per 1,000 live births.[3] Medical and technological advances have enabled a cohort of children with severe CP impairments to survive.[3] Despite the nonprogressive nature of their motor impairment syndromes, their clinical picture may change over time.[4] A variety of treatments[5] are intended to improve the child's functioning in their relevant environments, usually at home or school.[6] However, the effectiveness of these treatments is debated.[7] There is a need to quantify the efficacy of a treatment and to follow a child's status over time.[8] The first step in this process is to develop clinically relevant, valid, and reliable outcome measures.[9]

Although impaired arm and hand function are the main problems in about half the children with CP,[10] there is a lack of appropriate instruments for measuring the ability of the children to use their hands in daily activities[7] since most scales are focused on lower limb function. Moreover, the existing pediatric scales focused on fine motor functions (e.g., Pediatric Evaluation of Disability Inventory,[11] Activities Scale for Kids[6]) are not validated for children with CP. It is important to have evaluation instruments that are specifically applicable to the population being studied[9] and the purpose of this study is to develop the ABILHAND-Kids questionnaire, a measure of manual ability in children with CP.

Manual ability is a behavior. It can be defined as "the capacity to manage daily activities requiring the use of the upper limbs, whatever the strategies involved."[12] Manual ability is based upon upper limb function, but it also involves environmental (e.g., assisting devices, school education) or personal (e.g., motivational, cognitive and emotional status, compensatory behaviors) contextual factors.[13] Therefore, manual ability cannot be observed directly, but it can be inferred from a patient's perception of the difficulty of performing manual activities.[12] Adult patients who are most familiar with their own functional limitations are commonly considered as the gold standard to report their health status.[14] The use of parents as valid proxy reporters is advocated not only for very young children but also for school children and adolescents,[15] even though children at these ages have the ability to adequately communicate their perceptions.[16] The ABILHAND-Kids questionnaire was submitted to both children and their parents in order to compare the reliability of the reported perceptions.

Once the subjects' perceptions were collected, a linear measure[17] of manual ability was obtained according to probabilistic measurement models, the most promising being the Rasch model.[18] Provided that the behavioral data fit the requirements of the model, manual ability is measured as the log-odds of

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Table 1 *Sample description (n = 113)*

Age, y, mean (range)	10 (6–15)
Sex	
Male	67
Female	46
Handedness	
Right	55
Left	57
Ambidextrous	1
School education	
Mainstream	47
Type 1: mild mental retardation	1
Type 4: physical handicap	58
Type 8: learning disabilities	6
Home	1
Type of CP	
Tetraplegia/paresis	35
Diplegia	24
Hemiplegia/paresis	
Right	26
Left	28
GMFCS	
Level I: most independent motor function	50
Level II	26
Level III	12
Level IV	21
Level V: least independent motor function	4

CP = cerebral palsy; GMFCS = Gross Motor Function Classification System.

reported successful achievement in manual activities and is located on a linear scale. In this study, the ABILHAND-Kids questionnaire was developed to assess manual ability as perceived by children with CP or their parents. Its reproducibility was tested after a delay of approximately 1 month.

Subjects and methods. *Subjects.* The study was authorized by the ethics committee of the Université catholique de Louvain, Faculty of Medicine in Brussels, Belgium. The definition adopted for selecting children with cerebral palsy was "all non-progressive but often changing motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development."[19]

Subjects older than 6 years were recruited to focus on children with mature manipulative skills in activities of daily life.[20] Age, sex, handedness, level of school education, type of CP, and the Gross Motor Function Classification System[21] (GMFCS) were included as independent demographic and clinical indices in the validation analysis. The children, recruited through seven centers specialized in CP, exhibited a wide range in each index. Moreover, given that ABILHAND-Kids was designed as an interview-based questionnaire, children with a major intellectual deficit (IQ < 60) were excluded. As a result, 113 children with CP (67 boys and 46 girls; mean age, 10 years) were assessed by the same examiner. The sample description is provided in table 1.

Questionnaire development. The ABIHAND-Kids questionnaire was designed to cover the widest range of children's manual activities including both unimanual and bimanual activities. The preliminary questionnaire included 41 items derived from the ABILHAND questionnaire already validated for adult patients.[12,22] Thirty additional items were selected from various existing scales: the Pediatric Evaluation of Disability Inventory,[11] the Activities Scale for Kids,[6] the Denver Developmental Screening Test, versions I[23] and II,[24] and the Klein-Bell Activities of Daily Living Scale.[25] Finally, 48 items were devised to extend the range of activities explored by the questionnaire. The pool of 119 items was submitted to 27 experts on children with CP (8 physicians, 11 physiotherapists, 7 occupational therapists, and 1 educator). The experts were asked to 1) determine the relevance of the activities; 2) estimate the difficulty of each activity for a CP child with moderate disorder on a three-level scale (very difficult/difficult/easy); and 3) devise pertinent activities not included in the original item set. Fifty items were eliminated either because the experts considered them irrelevant (46 items) or because the analysis of the experts' responses through the Rasch model showed that they did not contribute to the definition of a unidimensional variable (4 items). Finally, five items were added to the test following the experts' suggestions.

The experimental version of ABILHAND-Kids involved 74 items. The questionnaire was submitted to children with CP and their parents. They were also asked to suggest activities considered relevant in daily life but not already included in the questionnaire. None of the activities proposed by the children or their parents was added to the questionnaire because the suggestions were not exclusively related to the upper limbs (e.g., swimming, bicycling) and thus could involve factors other than just manual ability.

Instrument. The experimental version of ABILHAND-Kids explored unimanual and bimanual activities completed without technical or human assistance. For each question, the children and their parents were asked to provide their perceived difficulty irrespective of the limb(s) actually used to perform the activity on a three-level scale: impossible (0), difficult (1), or easy (2). Activities not attempted in the last 3 months were not scored and were encoded as missing responses (4% of the data for the children and 5% for their parents).

Procedures. The French version of the questionnaire was presented separately to children with CP and their parents. The 74 items were randomly presented. Each item was presented verbally to the child by the examiner, while the parents filled in the questionnaire themselves in another room. Fourteen percent of the children attended boarding school so their activities were not observed daily by their parents. In these cases, the questionnaire was completed by the occupational therapists on behalf of the parents. The test-retest reliability was investigated by submitting the questionnaire a second time, after a delay of 25 ± 13 days, to the children and their parents or occupational therapists.

Data analysis. Children's and parent's responses were analyzed separately with the WINSTEPS Rasch analysis computer program.[26] The Rasch model[18] verified that successive response categories for each item represented increasing levels of ability and that thresholds between successive response categories are located in the anticipated order.[27] It required that the probability of endorsing any response category to an item depended solely on the patient's ability, the item difficulty, and the threshold difficulties. Patient measures, item, and threshold difficulties were then located on a single real-number line representing the measurement scale. The Rasch model can also be used to verify that all items line up on a unidimensional scale.[28] Given the location of the parameters on the linear scale, the model recalculates the response expected for each subject to each item. The similarity between the observed and expected responses to any item is reported by the software through two fit statistics[29]: 1) the outlier-sensitive fit statistic (OUTFIT) and 2) the information-weighted fit statistic (INFIT). The INFIT is more sensitive to unexpected responses from patients with an ability level near the item difficulty. The OUTFIT is more sensitive to unexpected responses from patients with an ability level far from the item difficulty. Another statistic, the point measure correlation coefficient (RPM), indicates the coherence of each item with the rest of the questionnaire. It is computed as the correlation coefficient between all patients' responses to an item and their measures on the overall questionnaire except for that particular item. Positive RPM values are expected when each item is coherent with the other questionnaire items.

Item selection. Starting from the 74 experimental items, indexes reported from successive analyses were used to select the items that constituted the final ABILHAND-Kids scale. Any item that did not meet any of the following criteria was eliminated.

An ordered rating scale. The subjects were asked to report their perceptions on a three-level scale: impossible (0), difficult (1), or easy (2). If the anticipated order of response categories was verified, subjects with a higher ability ought to select a higher response to any given item and subjects selecting a higher response for a given item ought to present a higher ability. When these conditions were not met, the order of thresholds between successive response categories was skewed, indicating that the rating scale was not used as anticipated for the particular item.[27] Only items having thresholds in the anticipated order were retained.

All items share the same discrimination. Though all items were answered according to the same three-level rating, the threshold locations (relative to the item location) could vary across items. In this case, the items are perceived with a different discrimination.[30,31] The difference in discrimination from one item to another complicates the clinical interpretation of scores since a given response has a different relative weight across all items. Therefore, items presenting a discrimination significantly different from the average (Z-test) were removed.

All items fit a unidimensional scale. Fit statistics (INFIT and OUTFIT) were used to detect items that did not satisfy the model requirement of unidimensionality. The acceptable range of fit statistics for a sample of 113 subjects is between 0.80 and 1.20 for the INFIT and between 0.40 and 1.60 for the OUTFIT.[32] Items presenting an INFIT lower than 0.80 or an OUTFIT lower than 0.40 are not considered to be a major threat to unidimensionality.[33] All items presenting an INFIT higher than 1.20 or an OUTFIT higher than 1.60 were removed.

Scale validation. To validate the difficulty hierarchy of the selected activities, four occupational therapists were independently asked to classify each as either 1) unimanual or 2) bimanual. Bimanual activities were further classified as either (2A) normally done with two hands but also manageable in several unimanual steps when using an adaptive strategy; (2B) requiring one hand to stabilize an object—not involving any finger—and the other hand to complete the activity; or (2C) requiring digital activity from both hands. In addition, the patient measures were validated according to the relationship between ABILHAND-Kids measures and different demographic (age, sex, handedness, school education) or clinical (type of CP, GMFCS) indices. A Pearson correlation coefficient was computed for continuous indices, a *t*-test for two groups of nominal indices, and a one-way analysis of variance for more than two groups of nominal indices. Finally, the item difficulty hierarchy between the parents and the 27 experts was compared through a differential item functioning (DIF) test.[34]

Scale reliability. A person separation reliability coefficient was determined as the ratio between the true measure variance (as expressed by the SD corrected for measurement error) and the observed (true + error) measure variance in the sample.[35] This index is analogous to the traditional internal consistency coefficient, Cronbach's alpha.[36] Moreover, test-retest reliability of the parents' responses was determined by the Pearson correlation coefficient. The invariance in the item difficulty hierarchy across the first and the second assessment was also tested through a DIF test.[34]

Results. *Children's versus parents' perceptions.* The children's and parents' responses to the questionnaire were analyzed separately. The analysis of the children's responses resulted in a 13-item questionnaire because most of the items (n = 54) showed a disordered rating scale. Moreover, five items did not fit a unidimensional scale and two items did not share the common discrimination. The analysis of the parents' responses resulted in a 21-item questionnaire because most of the items (n = 36) did not share the common discrimination. Moreover, 15 items did not fit a unidimensional scale and 2 items showed disordered thresholds. The analysis showed that the retained items were different in both groups and also

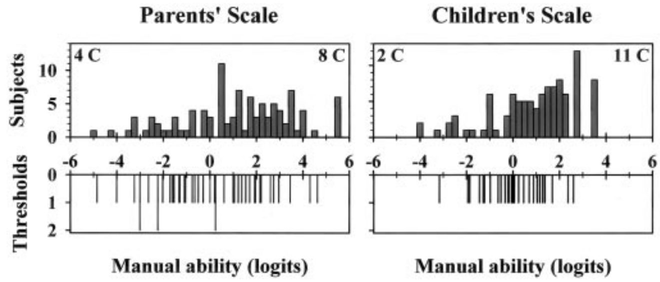

Figure 1. Manual ability scales as perceived by the children (13 items, 26 thresholds, right panel) and by their parents (21 items, 42 thresholds, left panel) and corresponding subjects distribution (top panels). The item threshold locations are well targeted on the subject measures on both scales. The floor and the ceiling effects are denoted by the number of children with extreme scores (either minimum or maximum) as marked on the upper corner of the distributions followed by a "C" (Children).

that the manual ability was better discriminated by the children's parents as compared to the children themselves.

The subjects' measures and the item thresholds distributions for both the parents' and the children's scales are presented in figure 1. The manual ability scales are calibrated in logits (i.e., log-odds units), a probability unit that expresses the natural logarithm of the odds of success (i.e., the pass/fail probability ratio). At any given ability level, a 1-logit difference between two children indicates that their odds of successful achievement of any activity are 2.7:1 (i.e., e^1:1), 2 logits have 7.4:1 odds, and 3 logits have $>$ 20:1 odds. The items are well targeted on the subjects in both scales. While both scales are able to successfully discriminate the manual ability of the subjects, the parents' scale covers a wider range than the children's scale, indicating a finer perception of item difficulties. Subjects measures are estimated over a range of 10.38 logits by the parents (leading to an odds ratio of over 32,000:1, i.e., $e^{10.38}$:1, between the most able and the least able child) while they cover only 7.54 logits according to the children's perceptions (leading to an odds ratio less than 2,000:1). Consequently, the subject measures can be discriminated with a greater than a 16 times higher resolution when using the parents' perceptions rather than the children's. Both scales present comparable floor and ceiling effects.

The children's lack of discrimination is emphasized even further when investigating the probability of each possible response ("impossible," "difficult," or "easy") to an item as a function of the child's ability. For any given item, a higher (i.e., easier) response is associated with a higher level of ability. However, the increase in manual ability required to answer "easy" rather than "impossible" is 2.66 times higher for the parents (3.24 logits) than for the children (1.22 logits). This indicates that the children's perception is more dichotomous; activities are perceived as either "impossible" or "easy" with very rare intermediate responses. However, the parents report a finer perception on their children's manual ability. They allow a better separation of the subjects according to their manual ability and allow a more precise measurement as reported by the person separation reliability of 0.94 for the parents and of 0.87 for the children.

The final version of the ABILHAND-Kids questionnaire

Table 2 *ABILHAND-Kids calibration for children with cerebral palsy*

Item	Difficulty, logits	SE, logits	INFIT, mean square	OUTFIT, mean square	RPM	Hands involvement*
a. Buttoning up trousers	3.00	0.22	0.88	1.55	0.58	2B
b. Buttoning up a shirt/sweater	2.67	0.22	0.77	0.65	0.58	2A
c. Opening a jar of jam	1.82	0.22	1.09	0.97	0.55	2B
d. Zipping up a jacket	1.34	0.21	1.00	0.98	0.57	2B
e. Rolling up a sleeve of a sweater	1.12	0.21	1.14	1.42	0.57	2A
f. Sharpening a pencil	0.98	0.22	1.05	0.98	0.58	2C
g. Putting on a backpack/schoolbag	0.58	0.22	1.12	0.97	0.56	2A
h. Zipping up trousers	0.52	0.21	1.13	1.14	0.57	2A
i. Fastening the snap of a jacket	0.33	0.21	1.13	1.03	0.57	2A
j. Squeezing toothpaste onto a toothbrush	0.29	0.22	1.00	1.44	0.59	2A
k. Unscrewing a bottle cap	0.08	0.22	1.07	1.33	0.57	2B
l. Opening a bag of chips	−0.09	0.22	1.18	1.21	0.59	2C
m. Opening the cap of a toothpaste tube	−0.41	0.23	0.80	0.62	0.61	2A
n. Washing the upper body	−0.61	0.22	1.13	1.06	0.60	1
o. Filling a glass with water	−0.62	0.23	1.08	1.17	0.58	2A
p. Opening a bread box	−1.01	0.24	0.89	0.68	0.62	2A
q. Taking off a T-shirt	−1.38	0.24	0.91	0.83	0.61	2A
r. Putting on a hat	−1.38	0.26	0.83	0.70	0.63	2A
s. Taking a coin out of a pocket	−1.63	0.26	0.66	0.45	0.64	1
t. Unwrapping a chocolate bar	−2.38	0.28	0.94	1.12	0.65	2A
u. Switching on a bedside lamp	−3.23	0.35	0.84	0.51	0.70	1
Mean	0.00	0.23	0.98	0.99		
SD	1.52	0.03	0.14	0.30		

* 1 indicates unimanual activities; 2 indicates bimanual activities manageable in several unimanual steps (2A), requiring stabilization with one hand and digital activity with the other (2B), requiring digital activity from both hands (2C).

was therefore exclusively built on the parents' perceptions because of the higher discrimination of the three-level rating scale, the wider range of measurement, and the higher person separation reliability.

Metric properties of ABILHAND-Kids. The calibration of the final 21-item ABILHAND-Kids scale is presented in table 2. The items are sorted, from top to bottom, in order of decreasing difficulty (range: 3.00 to −3.23 logits). Higher logit values indicate more difficult activities. Table 2 also reports the standard error (SE) associated with each item difficulty (mean: 0.23 logits; range: 0.21 to 0.35 logits). The mean square fit statistics indicate that all 21 items contribute to the definition of a unidimensional measure of manual ability. Moreover, all RPM are positive (all values $\geq$ 0.55) indicating that each item is coherent with the rest of the questionnaire and contributes to the measurement of the manual ability.

Description of ABILHAND-Kids. The definition and use of the ABILHAND-Kids scale is depicted in figure 2. The top panel shows the distribution of manual ability measures of the children as perceived by the parents.

The manual ability measures of the children with CP are obtained by converting the ordinal total scores into linear measures. The bottom panel illustrates the ogival relationship between the finite total raw scores and the infinite manual ability measures. This relationship is approximately linear between total scores of 11 and 30. Outside this central range, however, a unitary progression in total score accounts for an increasing amount of manual ability measure. In the central range, the change in manual ability measure corresponding to a unitary increment in total score from 19 to 20 scores is equal to 0.17 logits. Outside this central range, it increases to 0.86 logits for the same increment in total score from 1 to 2. This fivefold difference denotes the non-linearity of the total score.

The middle panel shows the expected response to a given item as a function of the underlying manual ability measure. By comparing the ability of a given child to the difficulty of each item, it is possible to determine the expected score of the child to the item. According to the parents' perception, a child with an ability of 0 logits would be expected to perform without difficulty the two easiest activities, to perform with some difficulties the average activities, and to fail to perform the three most difficult activities. In summary, according to the distribution of subject measures, 52% of the children in our sample should successfully perform all the listed activities easily or with some difficulty. Twelve percent of the children should perform all activities easily and 4% should not be able to perform any of the 21 ABILHAND-Kids items. Therefore, the range of difficulties of

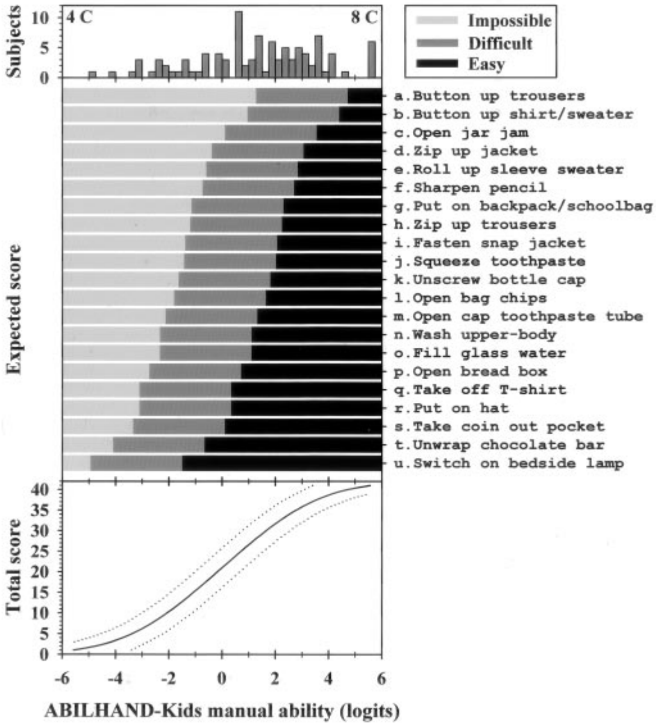

Figure 2. Top panel: distribution of manual ability measures of children with cerebral palsy according to their parents' perception. Twelve children with extreme scores cannot be measured by the ABILHAND-Kids scale because all activities were either impossible (4 C) or easy (8 C). Middle panel: a child's expected score to each item as a function of the underlying manual ability measure. A manual ability measure of zero is by convention set at the average item difficulty. Bottom panel: ogival relationship between total score and manual ability measure (solid line) and its 95% CI (dotted lines).

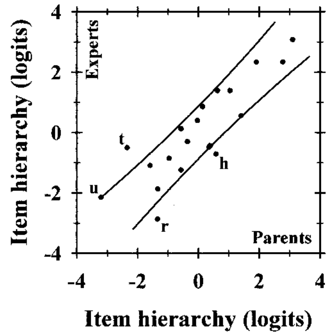

Figure 3. Differential item functioning plot of parents' and experts' perceived item difficulty hierarchy and 95% CI (solid lines) of the ideal invariance. Most difficult items are plotted in the top/right part of the figure. Items (dots) lying within the control lines have the same difficulty for both parents and experts groups. Four items lying outside the CI are identified by their labels.

the ABILHAND-Kids items fits the distribution of children's abilities.

Scale validation. The opinions of the four occupational therapists concerning the number of hands involved in each activity were consistent. The most frequently reported opinion is presented for each item in the last column in table 2. Most of the ABILHAND-Kids items are bimanual activities (2A-2B-2C, 86%), most of which can be managed in several unimanual steps when using an adaptive strategy (2A, 67%). The activities requiring more bimanual involvement tend to be more difficult.

No significant differences in ABILHAND-Kids measures were observed across age, sex, or handedness. A difference in ABILHAND-Kids measures was observed as a function of school education (t = 4.136, $p < 0.001$), type of CP (F = 9.621, $p < 0.001$), and the GMFCS (R = -0.640, $p < 0.001$). A post hoc analysis of the indices having a significant effect on ABILHAND-Kids measures indicates that the children with CP who were placed in a mainstream school present a higher manual ability than the children following a special education program. Diplegic and hemiplegic/paretic children have a higher manual ability than tetraplegic/paretic children. Finally, a higher independence in gross motor function is associated with a higher manual ability.

The differential item functioning plot presented in figure 3 compares the difficulty hierarchy of the items as perceived by the children's parents and by the experts. Most of the items lie within the 95% CI of the identity line indicating that the perceptions of the parents and the experts appear to be similar for the item hierarchy. There are four minor exceptions: "Zipping-up trousers" (h) and "Putting on a hat" (r) are estimated to be more difficult by the parents than by the experts, while "Unwrapping a chocolate bar" (t) and "Switching on a bedside lamp" (u) are estimated to be more difficult by the experts than by the parents.

Test-retest reliability. The test-retest reliability (delay: 25 ± 13 days) of the subject measures is presented in figure 4. Children's measures perceived by the parents at the first and the second assessment are correlated (R = 0.91, $p < 0.001$). Most of the measures lie within the 95% CI of the identity line indicating that the parents tend to estimate consistently their child's ability over time. Moreover, the difficulty hierarchy of all 21 ABILHAND-Kids items is maintained between the first and the second assessment, indicating that the ABILHAND-Kids scale is invariant across time.

Discussion. We sought to develop a measure of manual ability in children with CP using the Rasch model. We also compared children's and parents' perceptions. The ABILHAND-Kids questionnaire was constructed from the parents' perception in order to cover a wider measurement range of manual ability than was possible using the children's perception. The 21 items retained for the final ABILHAND-Kids measure show an ordered rating scale, share the same discrimination, and fit a unidimensional scale.

The children's manual ability is better discriminated by the parents than by the children themselves. The activities are perceived by the children as either "impossible" or "easy" with very rare intermediate responses. The more dichotomous perception of the children is consistent with the Piagetian theory where young children typically engage in dichotomous thinking and may therefore focus only on the

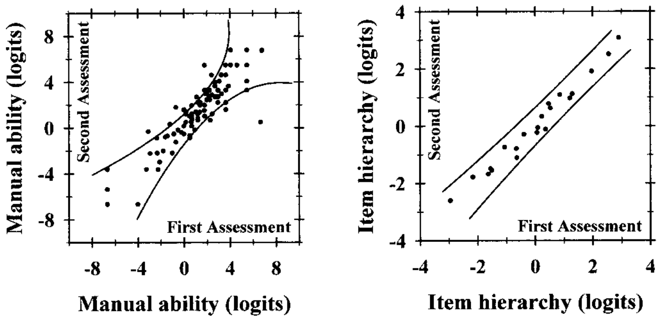

Figure 4. Left panel: relationship between the manual ability measures of the children as perceived by their parents at the first and the second assessment (delay: 25 ± 13 days) and 95% CI (solid lines) of the ideal invariance. More able children are plotted in the top/right part of the panel. Children measures (dots) lying within the control lines have the same estimated ability at the first and the second assessment. Right panel: differential item functioning plot of the item difficulty perceived by the children's parents across time and 95% CI (solid lines) of the ideal invariance. Most difficult items are plotted in the top/right part of the panel. All items (dots) are lying within the control lines indicating that they have the same estimated difficulty at the first and the second assessment.

two extremes of Likert-type rating scales.[37] The polychotomous parents' perception appears to be a more accurate source of information about manual ability than the dichotomous children's perception. However, the difference in discrimination between parents and children must be considered with caution, given the different modes of observation used in the two groups.[38,39] A face-to-face interview was used for the children and a written self-report for parents. A written self-report appears to be more appropriate for a clinical routine than a face-to-face interview where the interviewer is rarely the same. Moreover, face-to-face interviews may be influenced by the personality and the style of the interviewer, and the relationship with the subject.[16] The ABILHAND-Kids questionnaire was exclusively built on the parents' perception to reduce the error of measurement of manual ability as indicated by the higher person separation reliability observed in our sample (R = 0.94). In addition, the use of the parents' perception on behalf of the children's should allow, in the future, measurements of manual ability in all children with CP, including very young and severely impaired children and those with mental, psychological, emotional, attentional, or communicative disorders. The difficulty of just four items differs slightly between the parents and the experts. However, the differential item functioning of the four items is not high enough to compromise the clinical application of the scale. Parents might be better able than experts to judge which of the tasks are more difficult since they can observe their child's manual ability on a regular basis, capturing a sort of weighted average of the performance over long periods of time. Thus, two different modes of perception were used in the present study. Parents were asked to provide the observed difficulty of each activity for their child, while the experts were asked to provide the estimated difficulty of each activity for a "typical" CP child with moderate disorder. Nevertheless, further research will be needed to verify that parents' and experts' perceptions are really different for the four items, and to make any assumption about the reasons of these different points of view.

The 21 activities retained for ABILHAND-Kids involve both hands. Most of the unimanual activities included in the experimental version of the questionnaire were rarely perceived by the parents as "difficult," and consequently these activities were removed in the final version because the equal discrimination item selection criterion was not satisfied. This may be because the children either perform the unimanual activities easily using the less affected hand (usually the dominant hand) or cannot perform the activities because both hands are severely affected. In comparison, the activities requiring a higher bimanual involvement tend to be more difficult. The easiest bimanual activities performed every day by the children can often be managed in several unimanual steps using an adaptive strategy. The most difficult bimanual activities usually involve both hands, and sometimes involve bilateral digital activity. The perception of their difficulty might be complicated because alternative strategies might be adopted to complete these activities. Indeed, these activities might be performed with assisting devices, or by the parents instead of the child in order to prevent risk or save time.[40] Parents may also adapt their habits to facilitate some activities (e.g., by not overtightening a bottle). Nevertheless, all activities of the ABILHAND-Kids questionnaire retain the same discrimination and fit a unidimensional scale of manual ability, indicating that their difficulty was consistently perceived by the parents in our sample.

The 21 items of ABILHAND-Kids define a unidimensional measure of manual ability in children with CP and show a continuous progression in their difficulty. The standard errors associated with the item difficulties (mean: 0.23 logits) comply with the expectation for most variables.[41] Moreover, ABILHAND-Kids presents a good precision since the 21 items are well targeted on our sample expanding a wide range of functional states (R = 0.94). According to their parents, only 3.5% of the children with CP were not able to perform at least one item. All of these children were tetraplegic/paretic; they must be transported or use power mobility outdoors and in the community (GMFCS: Level IV) or were severely limited even with the use of assistive technology (GMFCS: Level V). Similarly, 7% of the children with CP were able to perform all items easily. All of these children were diplegic or hemiplegic/paretic and were at least able to walk indoors or outdoors on a level surface with assistive mobility devices (GMFCS: Levels I, II, III). The least measurable difference,[34] which corresponds to the smallest difference in linear measure obtained by a unit increment in total score, is equal to 0.19 logits in the central range of the scale (range: −1.85 to 1.65 logits). This indicates that in the central range, the resolution of ABILHAND-Kids is sufficient to differentiate the ability of two subjects if one has 50% probability to succeed in performing a given item and the other 45%. The overall precision of the scale is summarized by a good person separation reliability in this sample (R = 0.94). The observed invariance in the item hierarchy after a delay of approximately 1 month indicates that the ABILHAND-Kids manual ability measures are reproducible over time. The metric properties of ABILHAND-Kids give to the scale the potential to measure any sensible change in manual ability induced, for example, by surgery, rehabilitation, biomedical treatment, or the use of assisting devices. However, the responsiveness and the predictiveness of ABILHAND-Kids need to be investigated further in a longitudinal study.

The analysis of the relationship between ABILHAND-Kids measures and demographic or clinical indices appears not only as a form of validation of the scale but also as a clinical end point. Although ABILHAND-Kids measures are not related to age, sex, or handedness, a significant relationship was found with school education, type of CP, and GMFCS. Children with more severe forms of CP are high-intensity users of physiotherapy services[42] and are more likely to be placed in special schools which can better cope with treatment requirements. The significant relationship between ABILHAND-Kids measures and the type of CP confirms the previous reports[43-45] that children with hemiplegia/paresis and diplegia are less disabled in their fine and gross motor functions than children with teraplegia/paresis. Finally, ABILHAND-Kids measures are significantly related to the levels of GMFCS; a higher manual ability relates to a higher gross motor function. A similar relationship between bimanual fine motor function and the levels of GMFCS was previously found.[45] However, in this study, the relationship to gross motor function is not perfect, indicating that fine and gross motor functions are two distinct but complementary variables. The relationship between ABILHAND-Kids measures and some demographic and clinical indices that relate to the severity of the pathology (i.e., school education, type of CP, GMFCS) is age-independent. This suggests that the questionnaire is sensitive to the pathologic disruption of manual ability rather than to a maturation of manual ability, at least in CP children older than 6 years.

The Rasch model was used to construct and validate ABILHAND-Kids. It provides the calibration of the ABILHAND-Kids activities that can be sorted according to their estimated difficulty (see figure 2). The hierarchical nature of the scale identifies a child's spontaneous pattern of recovery given the current manual ability measurement. It can be used for goal setting in treatment planning. Furthermore, the Rasch model has the ability to detect discrepancies between the observed score to each item and the expected score, given the overall measure of the subject. More than a simple data quality control, it can be used to identify an idiosyncratic use of the questionnaire or diagnose behavioral peculiarities such as a misuse of adaptive strategies.

Finally, the Rasch model can be used to test the invariance of the manual ability variable defined by ABILHAND-Kids through differential item functioning tests.[34] The current metric properties of ABILHAND-Kids make an encouraging starting point for further investigation of its invariance across demographic or clinical patient subgroups, and for its application across various pediatric diagnostic groups and cultures. If the invariance in the item hierarchy is also verified across treatment, then ABILHAND-Kids will also provide a responsive outcome measure to monitor patient status across time and recovery.

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