Upper Limb Function of Children with Unilateral Cerebral Palsy After a Magic-Themed HABIT: A Pre-Post-Study with 3- and 6-Month Follow-Up

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ABSTRACT

Aims: To examine changes in upper limb function, and performance in everyday tasks, for children with unilateral cerebral palsy who participated in a magic-themed hand-arm bimanual intensive therapy (HABIT). Methods: Twenty-eight children participated; mean age 10 y 6 mo (SD 2 y 2 mo), n = 15 male and n = 13 female. Using a single group, pre-and post-test design, the magic-themed HABIT was delivered for 60 hours over 10 days. Bimanual and unimanual hand function were measured using the Assisting Hand Assessment (AHA) and Box and Blocks Test (BBT). Occupational performance was rated using the Canadian Occupational Performance Measure (COPM). Two parent questionnaires explored change in bimanual hand use in everyday activities; ABILHAND-Kids and Children’s Hand-use Experience Questionnaire (CHEQ). Assessments were completed pre-, immediately post, 3 months and 6 months after the intervention. Results: Friedman’s ANOVA revealed a significant improvement for COPM and CHEQ grasp subscale. Repeated measures ANOVA revealed a significant improvement in BBT, and ABILHAND-Kids, and no significant change for AHA. Conclusions: Children who participated in the magic-themed HABIT experienced improved occupational performance, unimanual skills, and parent ratings of performance in challenging everyday tasks.

Unilateral cerebral palsy (CP) has an impact on occupational performance due to movement limitations which are largely lateralized to one side of the body. Everyday functional activities that require the use and coordination of two hands together are difficult for children with unilateral CP to complete. As a result, children choose compensatory strategies, with varying success, or avoid bimanual activities. Effective interventions to improve upper limb function for children with unilateral CP incorporate principles of motor learning theory and neuroplasticity through structured, playful and activity-based tasks (Sakzewski, Ziviani, & Boyd, 2014). Bimanual therapy is a contemporary and evidence-based motor learning intervention that targets two-handed, coordinated practice.
A highly intensive form of bimanual therapy, hand-arm bimanual intensive therapy (HABIT) incorporates motor learning principles of task selection, structured practice, grading of tasks, feedback and home practice (Charles & Gordon, 2006). A typical HABIT intervention includes 60 hours of practice over 10 days (Charles & Gordon, 2006). Adaptations to HABIT to enhance outcomes include activities for the lower extremity (HABIT-ILE) (Bleyenheuft, Arnould, de Brito Brandão, Bleyenheuft, & Gordon, 2015), caregivers as interventionists (H-HABIT) (Ferre et al., 2017), and novel themes of circus (Sakzewski et al., 2011b) and magic (Green et al., 2013).

Themed upper-limb interventions provide children with unilateral CP an opportunity to develop hand skills in a fun and supportive environment that is different to usual therapy (Gilmore, Ziviani, Sakzewski, Shields, & Boyd, 2010; Hines, Bundy, Haertsch, & Wallen, 2018). Intensive practice and repetition are important components of implementing motor learning theory (Zwicker & Harris, 2009), which are difficult to achieve when children are not motivated to participate. Children who completed a circus-themed upper limb intervention had higher engagement and motivation levels when compared to those who completed individual occupational therapy sessions (Miller, Ziviani, Ware, & Boyd, 2016). Randomized controlled trial (RCT) research that explored the circus-themed HABIT, reported significant improvements in bimanual performance immediately after the intervention, as well as 6 months (Sakzewski et al., 2011b) and 12 months after (Sakzewski et al., 2011a). Previous single group research on the magic-theme approach to HABIT explored changes in upper limb function, with follow-up at 3 months (N=23) (Green et al., 2013). Bimanual performance, measured with the Assisting Hand Assessment (AHA), improved immediately after the intervention, although this change was not maintained at follow-up (Green et al., 2013).

Parent report of children’s hand use in everyday life is important in evaluating an intervention (Wallen & Stewart, 2015). Green et al. (2013) measured parents’ perceptions of their child’s hand use in daily task performance using Children’s Hand-use Experience Questionnaire (CHEQ) (Arnould, Penta, Renders, & Thonnard, 2004). They found a significant improvement in the percentage of bimanual tasks completed independently, which was maintained at the 3 month follow-up (Green et al., 2013). Psychometric research on CHEQ (Amer, Eliasson, Peny-Dahlstrand, & Hermansson, 2016), published after Green et al. (2013), recommended focusing only on the three valid subscales in CHEQ regarding effectiveness of grasp, time taken and the extent to which the child feels bothered when completing the task.

Occupational performance, often measured with the Canadian Occupational Performance Measure (COPM), is an important outcome to understand functional performance in daily life. Children experienced equal improvements in occupational performance in an RCT comparing HABIT with constraint-induced movement therapy (CIMT), with greater improvements experienced when the goals were directly practiced (de Brito Brandão, Gordon, & Mancini, 2012). Children who completed HABIT as part of the circus-themed upper limb intervention RCT, made significant improvements in occupational performance (COPM), which was maintained at 6- (Sakzewski et al., 2011b) and 12-month follow-up (Sakzewski et al., 2011a). Whether children experience improvements in occupational performance following a magic-themed HABIT has not been determined.
Green and colleagues (2013) provided preliminary evidence supporting the magic-themed HABIT as a useful and motivating upper limb intervention. However, their research did not measure occupational performance, and the parent report of child’s hand use, measured with CHEQ, focused on questions that have may not represent valid findings. The purpose of this study was to extend previous research on the magic-themed HABIT by: (1) using psychometrically sound measures of occupational performance and parent report of their child’s hand use, (ii) determining generalizability when implemented in a different health and cultural system of Australia, by clinicians and researchers who were not involved in developing magic-themed HABIT, and (3) exploring upper limb function, occupational performance and hand use in everyday tasks 6 months after the AMC, to also enable comparison with previous HABIT RCTs (Gordon et al., 2011; Sakzewski et al., 2011b).

**Methods**

A single-group, pre- and post-test design was used to examine changes experienced by children who engaged in the magic-themed intervention, called Amazing Magic Club (AMC). We measured activity-based outcomes immediately post, 3 and 6 months after AMC. We chose a single group design because of limited funding and time, and we were interested in understanding the feasibility and generalizability of the intervention in Australia prior to completing a randomized controlled trial. Ethics approval was obtained from the Cerebral Palsy Alliance Human Research Ethics Committee (NHMRC HREC: EC00402), and Queensland Children’s Health Services (RCH) Human Research Ethics Committee (HREC/14/QRCH/357). Parents or carers, and child participants aged 12 years and over, gave written informed consent.

**Participants**

Children were included if they had a diagnosis of unilateral CP with predominant spasticity; were aged between 7 y 6 mo and 16y; attended mainstream school; could follow a 2–3 step sequence; committed to the 10-day AMC and 6 additional sessions; spoke and understood English; and had an interest in learning magic. Children who received any new or altered upper limb interventions such as splinting, casting, or Botulinum toxin A injections in the 3 months before, or who were anticipating these interventions in the 6 months after AMC were excluded. Children with an intellectual impairment were excluded due to the high level of executive functioning required to learn the magic tricks in a group setting. We did not exclude children based on limitations in range of motion or active movement in the more affected hand. Two pilot AMCs were run in 2014 to consolidate the program in Australia; children who participated in these pilots were excluded. Children were recruited using the relevant state-based CP Register and/or through local children’s hospitals, social media posts and flyers in waiting rooms.

A total of 29 children with unilateral cerebral palsy (CP) completed one of three AMCs in 2015; Sydney, n = 8; Melbourne, n = 12; and Brisbane, n = 9. The average age of children was 10 y 6 mo (SD 2 y 2 mo); n = 15 were male and n = 13 were female. Participant characteristics are described in Table 1. Data from one child in Melbourne
Table 1. Characteristics and baseline results of child participants across AMC groups.

| Characteristics:                  | Sydney (n = 8) | Melbourne (n = 11) | Brisbane (n = 9) | ALL (n = 28) |
|-----------------------------------|----------------|--------------------|------------------|-------------|
| Sex (male/female)                 | 5/3            | 4/7                | 6/3              | 15/13       |
| Mean Age y:m                      | 9:3            | 11:9               | 10:1             | 10:6        |
| (SD; range)                       | (1:5; 7:8–12:3) | (2:3; 7:10–15:2)  | (1:7; 8:5–13:6)  | (2:2; 7:8–15:2) |
| Affected side (right/left)        | 3/5            | 5/6                | 6/3              | 14/14       |
| MACS (I/II/III)                   | 0/8/0          | 3/7/1              | 3/6/0            | 6/21/1      |
| GMFCS (I/II)                      | 0/8            | 3/8                | 3/6              | 6/22        |
| MAS wrist (0/1/1+2)               | 2/1/3/2        | 5/3/0/3            | 2/2/0/5          | 9/6/3/10    |
| N/a at T2/T3/T4                   | 0/1/1          | 0/1/1              | 0/1/5            | 0/3/7       |
| T1 Scores:                         |                |                    |                  |             |
| AHA units T1 Mean (SD)            | 60.2 (17.9)    | 62.4 (12.5)        | 56.7 (27.1)      | 59.9 (17.7) |
| COPM T1 Median (IQR: Q3-Q1)       |                |                    |                  |             |
| Performance                       | 2.8 (3.8 - 2.3) | 4.3 (5.5 - 3.2)  | 3.0 (4.8 - 2.4)  | 3.2 (4.9 - 2.8) |
| Satisfaction                      | 4.2 (5.0 - 3.1) | 5.3 (6.0 - 3.2)  | 5.0 (7.6 - 3.5)  | 5.0 (7.5 - 3.2) |
| COPM priority areas at T1         |                |                    |                  |             |
| Self-Care                        | 32             | 36                 | 32               | 103         |
| Productivity                      | 2              | 2                  | 0                | 4           |
| Leisure                           | 0              | 2                  | 0                | 2           |

AHA: Assisting Hand Assessment; COPM: Canadian Occupational Performance Measure; GMFCS: Gross Motor Functioning Classification System; MACS; Manual Ability Classification System; MAS wrist; Modified Ashworth Scale of wrist flexors measured with fingers extended; N/a, not available for follow-up assessments; T1: immediately preceding AMC; T2: immediately following AMC; T3: 3 months after AMC; T4: 6 months after AMC.

Figure 1. Participant flow diagram.
were excluded from analysis because, during the early stages of AMC, this child's predominant dystonic presentation became clear. Data analysis were therefore completed for 28 participants, including \( n = 11 \) from Melbourne. Details of children unavailable for follow-up are shown in the participant flow diagram (Figure 1).

Previous research on the magic-theme approach achieved a sample size of 23 participants; with an effect size of 0.80 (Cohen’s \( d \)) determined by pooling effect sizes from previous bimanual interventions (Green et al., 2013). We aimed for a sample size of 30 participants, based on this previous research on the same magic-themed intervention (Green et al., 2013). Our sample size was limited by time and financial constraints necessitating delivery of the AMC groups during school holidays in 2015, and by recommended group sizes of between 8 and 12 children. We completed a post hoc sample size calculation using our baseline data from our primary outcome measure (AHA, \( m = 59.9, SD = 17.7 \)). With our achieved sample \( N = 28 \), we did not achieve 80% power at the 0.05 significance level to detect change (Cohen’s \( d = 0.10 \)).

**Intervention**

AMC is a novel, magic-themed HABIT intervention consisting of 10 intensive 6-hour days. The magic-themed program was developed by Breathe Arts Health Research, further details of AMC using the TIDieR guidelines (Hoffmann et al., 2014) are available (Appendix). AMC follows the HABIT principles (Charles & Gordon, 2006): (i) task selection; (magic tricks are chosen to target specific movement difficulties for children with unilateral CP), (ii) practice (whole and part-task practice of magic tricks are incorporated into each day), (iii) grading (magic tricks vary in complexity of physical movements and cognitive sequencing), (iv) feedback (children receive intrinsic feedback from physically performing magic tricks, and extrinsic feedback from professional magicians) and (v) home practice (children are given homework each night). A typical day includes learning and practice of magic tricks, food preparation, performance rehearsals, craft activities and bimanual games (Green et al., 2013). AMC is completed in a theater space so that children can become familiar with performing on stage. AMC culminates in a performance for children to showcase their new magic skills. After AMC, children participate in six additional Saturday sessions held monthly for 3.5 hours at a local community center. Children received one-to-one support, feedback, and grading of task difficulty as appropriate from occupational therapy (OT) students. The OT students completed training before AMC, and participated in morning tutorials and afternoon debrief sessions throughout AMC. An investigator (AH) trained in AMC coordinated the intervention and additional monthly sessions, in collaboration with an administrative assistant, and an experienced OT. Two professional magicians were present to teach new magic tricks, to encourage practice, and to assist with performance rehearsals.

**Procedures**

All children attended the 10-day AMC; each AMC followed the same intervention protocol (Appendix). Adherence to the 60 hours of AMC was achieved by 75% of children (\( m = 59 \) hours, range = 48–60 hours). Attendance at the monthly sessions varied...
Child participants and their parents completed assessments at four time points: baseline (within 2 weeks of AMC commencing, T1); post-AMC (within 1 week of AMC completion; T2); 3 months (T3); and 6 months after the AMC (T4). The first author (AH) completed all assessments, with assistance from the fifth author (MW) on two occasions. All assessment points were approximately 1 hour in duration. Assessments were completed in a distraction-free room in a community center, at a site convenient for participating families. T3 and T4 assessments were completed during the 3rd and 6th additional monthly sessions.

**Measures**

At T1, children were classified using the Manual Ability Classification System (MACS) (Eliasson et al., 2006) and the Gross Motor Function Classification System (GMFCS) (Rosenbaum, Palisano, Bartlett, Galuppi, & Russell, 2008). The Modified Ashworth Scale (MAS) (Mutlu, Livanelioglu, & Gunel, 2008) was completed to quantify muscle tone of the wrist flexors with fingers extended (Table 1).

**Bimanual and Unimanual Hand Function**

The Assisting Hand Assessment (AHA) is an observational assessment completed as a play session to elicit typical bimanual performance. The AHA has sound psychometric properties (Holmefur & Krumlinde-Sundholm, 2016; Krumlinde-Sundholm, Holmefur, Kottorp, & Eliasson, 2007). The AHA raw score is transformed into AHA units (logit scale 0–100), with higher scores indicating higher ability, and a difference of 5 AHA units indicating a clinically important change (Krumlinde-Sundholm et al., 2007). In this study, we used the School Kids (≤12 years) and adolescent versions (≥13 years; sandwich making task). The AHA videos were scored by two certified raters blinded to the timing of assessment.

The Box and Blocks Test (BBT) is a reliable and valid measure of timed unimanual performance (Mathiowetz, Volland, Kashman, & Weber, 1985). Children completed BBT in accordance with published procedures (Mathiowetz et al., 1985); children were given 60 seconds to move small blocks from one box, across a partition, into another box.

**Occupational Performance**

The Canadian Occupational Performance Measure (COPM) evaluates perceived performance and satisfaction with performance on priority areas identified by caregivers or by child self-report (Law et al., 2005). Satisfactory to excellent evidence of validity, reliability, and responsiveness exists (Carswell et al., 2004; Cusick, Lannin, & Lowe, 2007). COPM performance and satisfaction are rated using two 10-point scales where a score of 10 represents strong performance and high satisfaction. A change of 2 or more points is interpreted as clinically meaningful (Carswell et al., 2004). We completed COPM with all parents, and some children, to identify priority areas relevant to address with an upper limb intervention. COPM priority areas were re-scored without access to earlier
scores at T2, T3 and T4. Child participants were not present during parent ratings, and vice versa. Children’s COPM results were examined for clinically meaningful change, the results were not statistically analyzed due to the small sample size ($N = 9$).

**Parent Report of Hand Use**

The ABILHAND-Kids questionnaire measures manual ability of children with CP, through parent perspective of their child’s ability to complete everyday tasks (Arnould et al., 2004). ABILHAND-Kids has evidence for good construct validity, responsiveness to change, and excellent test retest reliability (Bleyenheuft, Gordon, Rameckers, Thonnard, & Arnould, 2017). Wallen and Stewart’s (2015) review recommends ABILHAND-Kids for evaluating hand use in everyday tasks for children aged 6-15 years, the age range of the child participants in our study.

We also used the original Children’s Hand-use Experience Questionnaire (CHEQ), a 28-item questionnaire developed for children with unilateral impairment that explores parent or child perception of the experience of completing bimanual tasks. Evidence for test-retest reliability for the CHEQ is strong (Amer et al., 2016). Only parents completed the CHEQ in our study. Consistent with recommendations in the literature, we focused on the three subscales which have demonstrated validity; effectiveness of grasp, time taken and the extent to which the child feels bothered when completing the task (Amer et al., 2016). The two opening questions of CHEQ, that explore the number of tasks completed with one hand or two hands, are invalid in measuring outcome (Amer et al., 2016).

**Data Analysis**

Data were analyzed using Statistical Package for Social Sciences version 22 (SPSS). Prior to analysis, we reviewed the data to check for values that were out of expected range. Consequently, five AHAs were re-scored due to unusually large change scores from T1 to T2, and the average of the two scores was used in analysis. To further check AHA score reproducibility, a random selection of 10% ($n = 10$) of AHAs, were scored by an additional AHA rater who was independent to the study. Intraclass correlation ($ICC$), which describes similarity of the two AHA scores, was high ($ICC = 0.94$).

We used parametric (repeated measures ANOVA) and nonparametric tests (Friedman’s ANOVA) as appropriate to examine differences in scores from T1 to T4. A Holm–Bonferroni correction for multiple comparisons was used to interpret statistical significance on the nine ANOVAs ($p < 0.006$) (Holm, 1979). Post hoc analyses (paired sample $t$-tests for normally distributed variables, and Wilcoxon signed-rank tests for non-parametric variables) with Bonferroni correction were completed to examine the difference from baseline to follow-up assessments ($p < 0.002$). We had a complete data set at T1 ($N = 28$) and immediately post intervention T2 ($N = 28$), but missing data at T3 ($n_{missing} = 4$) and T4 ($n_{missing} = 7$) (Figure 1). To impute the missing data, we calculated the mean change from T2 to T3, and from T3 to T4, for each outcome measure using the data from the children who completed all assessment time points ($n = 21$).
Table 2. Outcome measures at all time points and results of statistical analysis.

| Measures (n = 28) | T1     | T2     | T3     | T4     | Mean or median difference, post hoc |
|-------------------|--------|--------|--------|--------|-----------------------------------|
| AHA units Mean (SD) | 59.9 (17.7) | 61.8 (18.6) | 59.3 (18.5) | 61.3 (18.8) | F = 4.0, p = 0.018, T1–T2 = 2.5, T1–T3 = 2.1, T1–T4 = 4.7, p < 0.001** |
| CMC > 5 logits (%) | 29     | 25.7   | 28.3   | 28.1   | F = 22.2, p < 0.001* |
| BBT-More-affected hand Mean (SD) | 36.1 (13.9) | 26.1 (14.9) | 25.7 (15.4) | 28.3 (15.5) | F = 10.7, p < 0.001* |
| BBT-Less-affected hand Mean (SD) | 47.3 (11.4) | 50.9 (12.1) | 51.7 (12.0) | 54.3 (11.2) | F = 10.7, p < 0.001* |
| COPM-P Parent. Median | 3.2    | 6.7    | 6.7    | 7.3    | p < 0.001* |
| IQR                | 2.8–4.9 | 5.1–7.5 | 5.1–8.0 | 5.9–8.9 | χ²(3) = 66.5 |
| CMC >2 points (%)  | 61     | 65     | 84     |        |        |
| COPM-S Parent. Median | 5.0    | 7.7    | 7.8    | 7.9    | p < 0.001* |
| IQR                | 3.2–6.0 | 6.2–8.9 | 6.1–9.0 | 6.7–9.3 | χ²(3) = 52.1 |
| CMC > =2 points (%)| 50     | 61     | 58     |        |        |
| COPM-P Child. Median (n=9) | 3.6    | 7.5    | 7.4    | 7.3    |        |
| IQR:               | 3.0–6.0 | 6.8–8.4 | 6.5–7.9 | 7.0–8.0 |        |
| CMC >2 points (%)  | 5.0     | 8.0    | 8.3    | 7.7    |        |
| COPM-S Child. Median (n=9) | 2.9–7.8| 6.5–9.8 | 7.9–9.5 | 7.2–8.0 |        |
| IQR:               | 2.5–3.5 | 2.5–3.4 | 2.5–3.4 |        |        |
| ABILHAND-Kids logits | 2.2 (1.9) | 2.5 (1.7) | 2.7 (2.0) | 2.9 (1.8) | F = 9.3, T1–T2 = 0.3, p = 0.011 |
| Mean, (SD).        | 2.2     | 2.5     | 2.7     | 2.9     | p < 0.001* |
| CHEQ. Grasp. Median | 2.8     | 3.0     | 2.9     | 3.0     | p = 0.005* |
| IQR                | 2.3–3.0 | 2.6–3.4 | 2.5–3.4 | 2.5–3.4 | χ²(3) = 13.0 |
| CHEQ. Time taken. Median | 2.8     | 2.9     | 2.8     | 2.8     | p = 0.027 |
| IQR                | 2.4–2.9 | 2.5–3.2 | 2.5–3.1 | 2.5–3.1 | χ²(3) = 9.2 |
| CHEQ. Bothered. Median | 3.2     | 3.3     | 3.3     | 3.4     | p = 0.201 |
| IQR                | 2.8–3.8 | 2.8–4.0 | 3.0–3.9 | 3.1–3.8 | χ²(3) = 4.6 |

AHA: Assisting Hand Assessment; BBT: Box and Blocks Test; COPM-P: Canadian Occupational Performance Measure-Performance; COPM-S: Canadian Occupational Performance Measure-Satisfaction; CHEQ: Children’s Hand-use Experience Questionnaire; T1: immediately preceding AMC; T2: immediately following AMC; T3: 3 months after AMC; T4: 6 months after AMC. CMC: clinically meaningful change. Data not imputed for CMC percentages. Range of scores; AHA 0–100, ABILHAND-Kids 0–6.7 to 6.7, COPM 1–10, CHEQ 1–4. χ², chi-square. * indicates significance at p < 0.006 for analysis of variance with Holm-Bonferroni correction for multiple comparisons. ** indicates significant at p < 0.002 for post hoc analyses (with Bonferroni correction).
We added, or subtracted, the mean change to the last available score for each child with missing data.

**Results**

Descriptive statistics and results of statistical analyses are presented in Table 2. Repeated measures ANOVA revealed no difference in scores for AHA. Eight children made a clinically meaningful improvement in AHA (≥ 5 AHA units) between T1 and T2. A significant difference was found in mean scores for the more-affected and less-affected hands using BBT; post hoc analyses revealed significantly more blocks transferred with the more-affected hand at T2 and T4 compared with T1, and for the less-affected hand at T3 and T4 compared with T1.

Sixty-two percent of COPM priority areas were related to bimanual dressing tasks, 20% to bimanual food preparation tasks, and 17% to using cutlery with two hands. We found a significant difference in COPM performance and satisfaction scores, with post hoc analyses revealing a significant increase in scores from T1 to all follow-up time points. Seventeen parents for COPM performance, and 14 parents for COPM satisfaction, perceived a clinically meaningful change (≥ 2 points) from T1 to T2. Eight of 9 children reported a clinically meaningful improvement from T1 to T2 in performance and 5 of 9 children for satisfaction with performance.

Repeated measures ANOVA showed a significant change in ABILHAND-Kids logit scores, with post hoc analyses indicating a significant increase from T1 to T4. Friedman’s ANOVA showed a difference for CHEQ effectiveness of grasp; and post hoc improvement from T1 to T4. We found no significant differences for CHEQ items pertaining to time taken to complete tasks, or the extent to which the child feels bothered.

**Discussion**

We examined bimanual and unimanual function, occupational performance, and parent report of hand use in everyday tasks of children who participated in AMC. Parents perceived a significant improvement in their child’s occupational performance, shown through statistically significant and clinically meaningful improvement in COPM performance and satisfaction priority areas. At AMC, there was no individual time set aside for specific goal practice, however, some COPM areas were often included as AMC homework, or completed coincidentally as part of pre-planned AMC activities (e.g., using a knife and fork to eat lunch). Improved occupational performance of individual priority areas reflects an improved independence in everyday life. Identifying and rescoring COPM priority areas with parents, who are important members of their child’s home and social environments, may have focused extra attention, and encouraged additional practice of the priority areas at home, which may have influenced outcomes (Sakzewski, Provan, Ziviani, & Boyd, 2015). In addition, while parents were blinded to previous scores, the potential for reporting bias is acknowledged; parents may have reported higher scores to please the researcher or because they were invested in their child improving. It is unclear, without a control group, whether these changes could be accounted for by typical change over time. In most cases, however, the priority areas
identified (e.g., dressing) reflected activities that are typically accomplished before the average age of the children in our study.

Children showed significant improvements in unimanual skills in the more-affected hand immediately after AMC, and for both hands after 6-months. The immediate improvement in unimanual hand function is consistent with previous single group research on magic-themed HABIT (Green et al., 2013) and with results from an RCT exploring a non-themed HABIT group (Gordon et al., 2011). In both studies, unimanual ability improved significantly at follow-up, although a different measure of timed unimanual performance was used (i.e., Jebsen Taylor Test of Hand Function). Our participants’ unimanual improvements may have encouraged an enhanced awareness and use of their more-affected hand, leading to improved occupational performance in individualized everyday tasks.

We found a significant improvement in ABILHAND-Kids, and in grasp effectiveness measured with Children’s Hand-use Experience Questionnaire (CHEQ), for our child participants at 6 months. HABIT-ILE RCT research also reported improvement in ABILHAND-Kids following the intensive intervention (Bleyenheuft et al., 2015). Previous researchers exploring the magic-themed HABIT (Green et al. 2013) used the CHEQ to measure parent report of everyday hand use. They did not report on the three valid subscales, so comparison with our study is not possible. The two questionnaires, ABILHAND-Kids and CHEQ, measure different constructs, with the CHEQ focusing on perceived experience of hand use and ABILHAND-Kids on perceived performance of bimanual tasks (Bleyenheuft et al., 2017). Both questionnaires complement the AHA (Bleyenheuft et al., 2017; Ryll, Bastiaenen, & Eliasson, 2017), but whether they complement each other is an area for future research.

Contrary to our hypothesis, we did not identify improvements in bimanual ability on the AHA. This is in contrast to previous findings for bimanual hand use following intensive bimanual intervention RCTs (Bleyenheuft et al., 2015; Gordon et al., 2011; Sakzewski et al., 2011b). The reasons for this finding are unclear, although treatment density and the age of our participants may be contributing factors. Although children at AMC were to spend 6 hours per day (60 hours) completing bimanual tasks, we did not measure density of training (e.g., the amount of repetitions within each activity) (Bleyenheuft et al., 2015; Sakzewski et al., 2015). Despite one-on-one interaction with an OT student, perhaps children did not complete sufficient bimanual practice. In addition, many of our school-aged children may have already developed their own alternate strategies for completing bimanual tasks.

Parents’ description of the AMC included observation of intrinsic motivation as children attempted challenging bimanual functional tasks, with some parents commenting that this may not have been due to physical improvement, but rather a result of the AMC experience (Hines et al., 2018). These qualitative findings are similar to the results in this current study as children improved in parent rating of performance of challenging bimanual tasks (COPM), and completion of everyday tasks (ABILHAND-Kids), although not in bimanual ability (AHA). Although we cannot support the transference of bimanual skills to functional and unpractised bimanual tasks, it is possible that AMC offers an experience that encourages motivation to attempt difficult bimanual tasks that were previously avoided.
Some children participating in intensive interventions experience more substantial changes than others. Our results included exploration of clinically meaningful change for individual children using available information from AHA and COPM. Similar to other HABIT studies (Green et al., 2013; Sakzewski, Ziviani, & Boyd, 2011c), age, or severity of movement (MACS) did not explain why some children made meaningful change while others did not.

This study is limited as there was no control group, and the sample size was small, which resulted in reduced power. We cannot attribute any changes described in this study as a result of the AMC experience. We were limited by time and funding resources to deliver the intensive intervention within 2-week school holiday periods in Australia. Whether themed approaches, such as AMC, dilute or enhance any of the key motor learning theory elements is an area for future research. Nonetheless, many of our findings are quite consistent with previous studies.

The clinical implications of this study are the potential for a motivating magic themed HABIT, to enhance occupational performance. Treatment density and the amount of practice and repetitions completed during interventions, as well as at home, are essential for understanding true dose and to interpret the outcomes experienced for each individual. Clinicians are encouraged to be cognizant of the strategies that older children and adolescents have already developed to complete bimanual tasks. Children and adolescents, who are likely to have participated in some form of occupational therapy from an early age, may require novel means for maintaining motivation to achieve a true and high dose of upper limb therapy.

**Conclusions**

Parent’s perceived an improvement in completion of difficult bimanual priority areas for their children who took part in AMC. Our findings also indicate improvement in unimanual skills and completion of everyday tasks. Although our AHA findings are contrary to those of previous researchers, our results suggest that there may be other aspects of the magic-themed intervention, such as motivation, that support more independent completion of bimanual everyday activities.

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Amer, A., Eliasson, A. C., Peny-Dahlstrand, M., & Hermansson, L. (2016). Validity and test–retest reliability of Children’s Hand-use Experience Questionnaire in children with unilateral cerebral palsy. Developmental Medicine & Child Neurology, 58(7), 743–749. doi: http://doi.org/10.1111/dmcn.12991

Arnould, C., Penta, M., Renders, A., & Thonnard, J.L. (2004). ABILHAND-Kids: A measure of manual ability in children with cerebral palsy. Neurology, 63 (6), 1045–1052.

Bleyenheuft, Y., Arnould, C., Brandao, M. B., Bleyenheuft, C., & Gordon, A. M. (2015). Hand and arm bimanual intensive therapy including lower extremity (HABIT-ILE) in children with unilateral spastic cerebral palsy: A randomised trial. Neurorehabilitation and Neural Repair, 29(7), 645–657. doi: http://doi.org/10.1177/1545968314562109

Bleyenheuft, Y., Gordon, A. M., Rameckers, E., Thonnard, J. L., & Arnould, C. (2017). Measuring changes of manual ability with ABILHAND-Kids following intensive training for children with unilateral cerebral palsy. Developmental Medicine & Child Neurology, 59(5), 505–511. doi: http://doi.org/10.1111/dmcn.13338

Carswell, A., McColl, M., Baptiste, S., Law, M., Polatajko, H., & Pollock, N. (2004). The Canadian occupational performance measure: A research and clinical literature review. Canadian Journal of Occupational Therapy, 71(4), 210–222. doi: http://doi.org/10.1177/000841740407100406

Charles, J., & Gordon, A. M. (2006). Development of hand-arm bimanual intensive training (HABIT) for improving bimanual coordination in children with hemiplegic cerebral palsy. Developmental Medicine & Child Neurology, 48(11), 931–936. doi: http://doi.org/10.1111/j.1469-8749.2006.02039a.x

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

de Brito Brandão, M., Gordon, A. M., & Mancini, M. C. (2012). Functional impact of constraint therapy and bimanual training in children with cerebral palsy: A randomized controlled trial. American Journal of Occupational Therapy, 66(6), 672–681. doi: http://doi.org/10.5014/ajot.2012.004622

Eliasson, A. C., Krumlinde-Sundholm, L., Röschlad, B., Beckung, E., Arner, M., Öhrevall, A.-M., & Rosenbaum, P. (2006). The Manual Ability Classification System (MACS) for children with cerebral palsy: Scale development and evidence of validity and reliability. Developmental Medicine & Child Neurology, 48(7), 549–554. doi: http://doi.org/10.1111/j.1469-8749.2006.tb01313.x

Ferre, C. L., Brandão, M., Surana, B., Dew, A. P., Moreau, N. G., & Gordon, A. M. (2017). Caregiver-directed home-based intensive bimanual training in young children with unilateral spastic cerebral palsy: A randomized trial. Developmental Medicine & Child Neurology, 59(5), 497–504. doi: http://doi.org/10.1111/dmcn.13330

Gilmore, R., Ziviani, J., Sakzewski, L., Shields, N., & Boyd, R. (2010). A balancing act: Children’s experience of modified constraint-induced movement therapy. Developmental Neurorehabilitation, 13(2), 88–94. doi: http://doi.org/10.3109/17518420903386161

Gordon, A. M., Hung, Y.-C., Brandao, M., Ferre, C. L., Kuo, H.-C., Friel, K., ... Charles, J. R. (2011). Bimanual training and constraint-induced movement therapy in children with...
hemiplegic cerebral palsy: A randomized trial. *Neurorehabilitation and Neural Repair*, 25(8), 692–702. doi: http://doi.org/10.1177/1545968311402508

Green, D., Schertz, M., Gordon, A. M., Moore, A., Schejter Margalit, T., Farquharson, Y., ... Fattal-Valevski, A. (2013). A multi-site study of functional outcomes following a themed approach to hand-arm bimanual intensive therapy for children with hemiplegia. *Developmental Medicine & Child Neurology*, 55(6), 527–533. doi: http://doi.org/10.1111/dmcn.12113

Hines, A., Bundy, A. C., Haertsch, M., & Wallen, M. (2018). A magic-themed upper limb intervention for children with unilateral cerebral palsy: The perspectives of parents. *Developmental Neurorehabilitation*, 1–7. doi: https://doi.org/10.1080/17518423.2018.1442372

Hoffmann, T. C., Glasziou, P. P., Bouton, I., Milne, R., Perera, R., Moher, D., ... Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal*, 348, g1687. doi: http://doi.org/10.1136/bmj.g1687

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65–70. doi: http://doi.org/10.2307/4615733 [Database]

Holmefur, M., & Krumlinde-Sundholm, L. (2016). Psychometric properties of a revised version of the Assisting Hand Assessment (Kids-AHA 5.0). *Developmental Medicine & Child Neurology*, 58(6), 618–624. doi: http://doi.org/10.1111/dcmn.12939

Krumlinde-Sundholm, L., Holmefur, M., Kottorp, A., & Eliasson, A. (2007). The Assisting Hand Assessment: Current evidence of validity, reliability, and responsiveness to change. *Developmental Medicine & Child Neurology*, 49(4), 259–264.

Law, M., Baptiste, S., Carswell, A., McColl, M., Polatajko, H., & Pollock, N. (2005). *Canadian occupational performance measure* (4th ed.). Ottawa: CAOT Publications ACE.

Mathiowetz, V., Volland, G., Kashman, N., & Weber, K. (1985). Adult norms for the Box and Block Test of manual dexterity. *American Academy of Neurology*, 39(6), 386–391. doi: http://doi.org/10.1054/aotj.1986.0386

Miller, L., Ziviani, J., Ware, R. S., & Boyd, R. N. (2016). Does context matter? Mastery motivation and therapy engagement of children with cerebral palsy. *Physical & Occupational Therapy in Pediatrics*, 36(2), 155–170. doi: http://doi.org/10.3109/01942638.2015.1076556

Mutlu, A., Livanelioglu, A., & Gunel, M. (2008). Reliability of Ashworth and Modified Ashworth Scales in children with spastic cerebral palsy. *BMC Musculoskeletal Disorders*, 9(1), 44. doi: http://doi.org/10.1186/1471-2474-9-44

Rosenbaum, P., Palisano, R., Bartlett, D., Galuppi, B., & Russell, D. (2008). Development of the Gross Motor Function Classification System for cerebral palsy. *Developmental Medicine & Child Neurology*, 50(4), 249–253. doi: http://doi.org/10.1111/j.1469-8749.2008.02045.x

Ryll, U. C., Bastiaenen, C. H. G., & Eliasson, A. C. (2017). Assisting Hand Assessment and Children’s Hand-Use Experience Questionnaire: Observed versus perceived bimanual performance in children with unilateral cerebral palsy. *Physical & Occupational Therapy in Pediatrics*, 37(2), 199–209. doi: http://doi.org/10.1080/01942638.2016.1185498

Sakzewski, L., Provan, K., Ziviani, J., & Boyd, R. N. (2015). Comparison of dosage of intensive upper limb therapy for children with unilateral cerebral palsy: How big should the therapy pill be?. *Research in Developmental Disabilities*, 37, 9–16. doi: http://doi.org/10.1016/j.ridd.2014.10.050

Sakzewski, L., Ziviani, J., Abbott, D., Macdonell, R., Jackson, G., & Boyd, R. N. (2011). Equivalent retention of gains at 1 year after training with constraint-induced or bimanual therapy in children with unilateral cerebral palsy. *Neurorehabilitation and Neural Repair*, 25(7), 664–671. doi: http://doi.org/10.1177/1545968311400093

Sakzewski, L., Ziviani, J., Abbott, D., Macdonell, R., Jackson, G., & Boyd, R. N. (2011). Randomized trial of constraint-induced movement therapy and bimanual training on activity outcomes for children with congenital hemiplegia. *Developmental Medicine & Child Neurology*, 53(4), 313–320. doi: http://doi.org/10.1111/j.1469-8749.2010.03859.x

Sakzewski, L., Ziviani, J., & Boyd, R. N. (2011). Best responders after intensive upper-limb training for children with unilateral cerebral palsy. *Archives of Physical Medicine and Rehabilitation*, 92(4), 578–584. doi: http://dx.doi.org/10.1016/j.apmr.2010.12.003
Appendix A: TIDieR checklist for AMC

The TIDieR (Template for Intervention Description and Replication) Checklist*: Information to include when describing an intervention and the location of the information

| Item number | Item                                                                 | Primary paper (page or appendix number) | Other † (details) |
|-------------|----------------------------------------------------------------------|-----------------------------------------|------------------|
| 1.          | BRIEF NAME AMC (Amazing Magic Club)                                  | 1                                       |                  |
| 2.          | WHY AMC is a novel themed Hand-Arm Bimanual Intensive Therapy (HABIT) for children with unilateral cerebral palsy. AMC is based on principles of the motor learning theory, in order to achieve improvements in upper limb performance. | 2                                       |                  |
| 3.          | WHAT - Materials Child participants are given a ‘magic kit’ on the first day of AMC. The contents of the ‘magic kit’ include props required to learn and perform each magic trick. The magic tricks chosen as part of AMC are protected by intellectual property of Arts Health Institute (AHI)**. Materials were also required for craft activities, outdoor gross motor games, food preparation and meal times. All children had access to the same materials, there was no individualisation in materials given. | n/a                                     |                  |
| 4.          | WHAT - Procedures At AMC, children learn magic tricks and performance skills from professional magicians. On the first day of AMC, magicians perform to parents and children to showcase some magic tricks that the children will learn. During every other morning at AMC, after the children arrive, they are allocated to an occupational therapy student, their ‘magic helper’ for the day, and the children begin to revise magic tricks previously learnt. The magicians teach two or three new magic tricks to the children each day. Children participate in food preparation of salad ingredients, and all meals are delivered by caterers. Caterers are given instructions to provide meals that encourage the use of a knife and fork, for example large pieces of chicken, sausages or quiche. The children assist to wash the lunch dishes and clean the lunch area. In the afternoon, children participate in outdoor bimanual games, such as ball games. Following this, children also complete craft activities such as sewing together their magician’s costumes. The last task of the day is to write homework before the occupational therapy students hand over details of accomplishments of the day and requirements for homework to parents. This schedule is followed throughout the two weeks in the lead up to the performance at the end of AMC. | 2                                       |                  |

(continued)
Appendix. Continued.

| Item number | Item                                                                 | Where located                                                                                     | Primary paper (page or appendix number) | Other † (details) |
|-------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|----------------------------------------|-------------------|
| 5.          | WHO PROVIDED The AMC team consists of occupational therapists (OT), one admin assistant, magicians and occupational therapy students. Two OTs were trained in the AMC programme by AHI in Australia. Each AMC OTs had at least 5 years’ experience working with children with unilateral cerebral palsy and in paediatric rehabilitation. Only one OT was present at AMC at a time, and at each monthly follow-up session. Magicians had at least 10 years’ experience as professional magicians in the performance industry. A research OT (PhD candidate) was also trained in AMC, and was present at all AMCs and monthly catch-ups, to collect data and to provide assistance where needed. Occupational therapy student ‘magic helpers’ were allocated to children on a one-to-one basis. OT students attended morning tutorial sessions that were between 30 to 60 minutes on topics such as motor learning theory or intervention for children with unilateral cerebral palsy. Students also participated in afternoon debrief sessions, of the same duration, to discuss grading tasks of individual children, and plan for the next day. OT students were different for each AMC group depending on where it was completed. | 4                                                                                           |                                       |                   |
| 6.          | HOW All AMC interventions were provided face to face, in groups of between 8 and 12 children. Children received one-to-one assistance from occupational therapy students. | 2                                                                                           |                                       |                   |
| 7.          | WHERE AMC was provided within a theatre space with a stage, large room, access to an outdoor area, and toilet and kitchen facilities. The monthly catch-ups were held in a community centre with access to indoor and outdoor areas, and within 8km of the original AMC intervention venue. | 4                                                                                           |                                       |                   |
| 8.          | WHEN and HOW MUCH Children participated in one of three AMCs in 2015. AMC is a 10 day programme completed over a 12 day school holiday period (13 day period for one group to account for an Easter Public Holiday). Time each day was from 10am to 4pm. Children also attended six monthly catch-up sessions that ran for 3.5 hours on a Saturday afternoon (12:30pm - 4pm). The intervention was provided free of charge for families. All children attended AMC; adherence to the 60 hours of AMC was achieved by 75% of participants (average = 59 hours, range = 48 - 60 hours). Attendance at the monthly sessions varied (m = 4, range = 0-6). | 2                                                                                           |                                       |                   |
| 9.          | TAILORING As the children developed skills and confidence during AMC, adjustments to increase the challenge were discussed at each afternoon debrief session. Debrief sessions were held for between 30 and 60 minutes to discuss each individual child and for the OT to assist students with strategies and options for grading tasks for the child. | 2                                                                                           |                                       |                   |
| 10.         | MODIFICATIONS The intervention was delivered in the same way for all three AMCs. Following each AMC, some parents gave suggestions to improve the intervention, for example to provide opportunities for parents to meet and socialise, and regarding the number of parental sessions. | n/a                                                                                         |                                       |                   |

(continued)
Appendix. Continued.

| Item number | Item                                      | Where located |
|-------------|-------------------------------------------|---------------|
|             | location of AMC. These suggestions will be used to plan future AMCs. The suggestions were not put in place during AMC in order to avoid changing the experience for families yet to commence AMC. |               |
| 11.         | HOW WELL All staff attended a one day training session prior to AMC, run by AHI and based on the programme developed by Breathe Arts Research. In addition, the PhD candidate and the two magicians completed training of the programme in the UK by Breathe Arts Research. Two AMCs were delivered prior to research commencing; two Breathe staff attended one pilot to ensure it was being delivered in the correct way. | 4             |
| 12.‡        | FIDELITY The same OTs, research OT and magicians were involved in all three AMCs. The OT students were different for each group. Although all staff completed training, and participated in afternoon debrief sessions, there was no formal attempt to measure fidelity of AMC. With regard to child participants, four children withdrew from the study prior to the three month assessment time point, and an additional 3 children withdrew prior to the 6 month assessment time point. | 8             |

** The Arts Health Institute who owned the rights to AMC went into liquidation in November 2017. For additional information regarding the magic-themed programme, contact Breathe Arts Health Research (http://breatheahr.org/).