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The influence of object size on discrete bimanual co-ordination in children with hemiplegic cerebral palsy

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Abstract

Purpose: To examine the influence of perturbation of object size on the nature and extent of interlimb coupling in children with hemiplegic cerebral palsy.
Method: Participants completed a number of trials reaching and grasping unimanually and bimanually to a small cube (1.5 cm) and a large cube (6 cm). Both 3D kinematic data and video data were gathered and qualitative descriptions of the video data were made.
Results: It was found that object size did influence the nature and extent of bimanual coupling. As in previous studies this varied from participant to participant and either or a combination of temporal, spatial, or postural coupling was observed. In some cases the hemiplegic hand was influenced by the non hemiplegic hand, while in others it was the reverse.
Conclusions: The influence of context and the individual nature of children with cerebral palsy observed in this paper must be considered by those in rehabilitation. Additionally, the therapist might be able to use the natural tendency to couple to assist the functional control of the hemiplegic side.

Introduction

Manual activities such as reaching, grasping and manipulation form a fundamental part of our daily lives. Our arms and hands operate in a variety of differing contexts in which they have to adapt or modify their movements to achieve particular tasks or goals. However, many manual tasks necessitate the hands working together, either asymmetrically or symmetrically. Bimanual tasks, in which the hands are producing the same movement, are easier to control, anyone who has attempted to learn to play the piano being well aware of the difficulty in training the hands to perform different tasks at the same time. When moving the upper limbs there is a tendency for these movements to be coupled in terms of time, space, and posture. The phenomenon of interlimb coupling is an area that has been well researched within a large body of literature concerned with the processes involved in controlling such movements.[1–5] This work has primarily focused on 'non disabled' individuals.

More recently, researchers have turned their attention to bimanual coordination following brain damage. It has been found that children with hemiplegic cerebral palsy couple their limbs when moving bimanually.[6–10.] One of the prime findings in the study of Utley and Sugden[7] was that every child showed some form of interlimb coupling, most prevalent with respect to time and the spatial trajectory of the hand, and to a less degree with respect to hand posture. However, the manner in which this was established was not equivocal; either one of the hands slowed down, speeded up, or both hands adapted. Steenbergen *et al.*[9] provided a detailed examination of the coordination pattern of uni- and bimanual reaching and grasping movements in participants with spastic hemiparesis. For the unimpaired hand it was found that the intersegmental joint coupling was high, but was consistently lower in the impaired side. This was suggested as being indicative of more independently controlled segments at the impaired side. Steenbergen *et al.*[8] studied children with hemiplegic cerebral palsy when they had to perform unimanual and bimanual movements under speeded conditions. As in the study by Sugden and Utley,[6] asymmetry between both hands decreased under bimanual responding, albeit more dramatically. However, the manner in which this

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high degree of temporal invariance was established differed from that in the study of Sugden and Utley.[6] Almost always participants slowed down their unimpaired hand up to the level of the impaired hand. Similar to the study of Sugden and Utley[6] large intra- and inter-individual differences were found for the performance of the impaired hand. Interestingly, Brown,[11, 12] examining hemiplegic children on a number of manual functioning and neurological tests, made the clinical observation that the use of the unaffected hand had a marked effect on muscle tone and electro-myographic activity on the affected side. As children with hemiplegic cerebral palsy have a range of difficulties when moving unimanually the application of bimanual movement may have implications for rehabilitation.

The influence of contextual factors such as object property, task goal, and speed of movement is a major question in movement control research, especially in the domain of rehabilitation research.[10, 13–16] The question of how contextual factors influence movement characteristics has been addressed in both non disabled and cerebral palsied populations. In non disabled populations, contextual demands were shown to influence a variety of measurable outcomes during reaching and grasping.[17–20] Object size was shown to influence the type of grip employed as well as the kinematic characteristics of the transport to the object.[18, 21] In cerebral palsied populations, rehabilitation research (physiotherapy as well as occupational therapy) has repeatedly shown that the use of added-purpose activity is more effective than rote exercise for increasing the active range of motion in disabled individuals.[13, 14, 22] In addition, functional tasks were shown to provoke more consistent and ‘appropriate’ movement behaviour than non-functional tasks,[14] with movement execution becoming smoother in more functional task settings. More recently, Steenbergen, Meulenbrok and Rosenbaum (in press) showed that more meaningful tasks facilitate the planning of grips. These findings indicate that context may provide a useful manipulation when setting up training programmes for the rehabilitation of brain-damaged patients.

In the current study we looked at the influence of object size on interlimb coupling and the components of reaching and grasping. The main aim is to examine the influence of the non hemiplegic limb on the hemiplegic limb during bimanual reaching and grasping and to further examine how contextual perturbations may influence the nature and extent of any coupling elicited. For children with hemiplegic cerebral palsy who may have a range of difficulties when performing unimanual tasks[23, 24] bimanual movements may provide functional solutions for the more affected side. Within this group, each individual acts as his/her own control when comparing unimanual reaching and grasping in impaired and non-impaired limbs with bimanual reaching and grasping.[6, 7] Multiple recording methods were employed to obtain a better picture of the nature and extent of coupling under bimanual responding.

Methods

PARTICIPANTS

Children with hemiplegic cerebral palsy were involved who were able to make a reach and grasp and had an understanding of the task demands. Eight children aged 5 to 11 took part in the study (mean age: 8.1 years, s.d.: 1.9 years). Permission was gained from the parents and the child. Details on the children are found in table 1.

PROCEDURES

The experimental situation was set up carefully to ensure that the data collection was as accurate and as standardized as possible. This involved positioning the cameras and calibrating the 3D system. The height of chair and table were adjusted to suit the anatomical characteristics of each subject. The two tasks in the experiment were explained to the subject and demonstrations were given. Participants reached and grasped a cube/s unimanually and bimanually at their preferred speed. The order of reaching and grasping was alternated so that some participants reached first with the hemiplegic hand and then with the non hemiplegic hand and finally with both hands together, while others started with the non hemiplegic side. The order of reaching in terms of size of cube was also alternated.

Task

In this experiment the children were asked to perform two tasks.

Reach and grasp. (Small cube).
Reach and grasp (Large cube).

After three practice trials the children completed three trials for each cube with each hand, and three trials bimanually. In all the experiments simple instructions were given to the children and they were not told how to pick up the cube. The data collection took between 20 and 30 min for each subject. All trials were used in the analysis.

Table 1 Participant's details for those involved in the experiments

Child	*Age*	*Hemi hand*	*Medical information*
1. AR	5.7	Right (moderate)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
2. SW	5.8	Left (severe)	Athetoid hemiplegia. No evidence of involvement of non hemiplegic side
3. SM	7.1	Right (severe)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
4. MT	8.2	Left (mild)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
5. AW	8.3	Right (moderate)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
6. AB	8.4	Right (severe)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
7. JF	10.1	Right (severe)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side
8. MJ	11.0	Left (mild)	Spastic hemiplegia. No evidence of involvement of non hemiplegic side

Cameras and camera positions

A video camera was placed directly in front of the participants at a height of 1.80 m and three cameras were placed on the ceiling in front of the participants at a height of 2.65 m.

Placement of markers

The markers used in these experiments were luminous lightweight spheres 1 cm in diameter, and were placed on the shoulder, elbow, wrist, first digit and thumb of each subject. This was done in order to measure arm transport and grasp aperture.

Target/object

The objects were wooden cubes, the small cube was 1.5 cm (cubed) and the large cube 6 cm (cubed). The cubes were placed 20, 25, or 30 cm away from the subject in the sagittal direction, according to the size of the child. A template was attached to the desk/table top so that the distance of the objects from the participants was standardized.

METHODS OF ANALYSIS

In order to obtain a full picture of the movement, multiple methods of analysis were used. Both kinematic and video data were analysed providing information on both the transport and grasp components. Kinematic measures were taken at 50 Hz and during data collection the threshold level was set to reduce noise. Other than this no filter was used. The videotapes were examined using a Panasonic video recorder with frame-by-frame facility (50 fps). Participants were judged on changes in trajectory, changes in posture, and spatial changes by viewing the movement frame by frame. A descriptive summary was made of each action for each child. Analysis was completed by the author and two independent researchers with a high degree of inter-rater reliability $r = 0.89$ and $r = 0.97$.

Results

Both group and individual data are presented, with a representative selection of the individual data included.

VELOCITY PROFILES

Velocity profiles were produced for both the wrist and index finger when moving unimanually and bimanually. The velocity profiles provide strong evidence of temporal coupling when moving bimanually. When reaching for the small cube in some participants ($N = 3$) it is the movement of the non hemiplegic hand which appears to have influenced the hemiplegic timing when moving bimanually. Figure 1 displays an example of the non hemiplegic hand dominating the timing of the bimanual movement when reaching for the small cube. In others ($N = 2$) both hands appear to have adjusted their timing to each other during the bimanual condition. Finally, in some participants ($N = 3$) it is the timing of the hemiplegic hand which appears to have dominated the movement during the bimanual condition. A similar pattern emerges when reaching for the large cube. In three participants it is the movement of the non hemiplegic side which dominates the movement during the bimanual condition. In three other participants it is the hemiplegic hand which dominates the movement and in two participants both hands adjust their timing during the bimanual movement.

Figure 2 is included as an example of temporal coupling with the movement of the non hemiplegic side dominating the timing during the bimanual condition when reaching for the large cube.

Across participants, mean velocities of the movement during reaching for the small and the large cube provided evidence of temporal coupling especially at the digits. During the unimanual condition there was a mean difference between the wrists of 0.14 m/s (SD = 0.04) and a mean difference between the digits of 0.18 m/s (SD = 0.07). When moving bimanually this decreased to 0.10 m/s (SD = 0.63) at the wrists and 0.07 m/s (SD = 0.05) at the digits. A *t*-test for dependent samples was significant (t[df7] = 6.17 $p < 0.05$) when reaching for the small cube but failed to reach significance when reaching for the large cube (t[df7] = 2.10 $p > 0.05$). When reaching for the large cube during the unimanual condition there was a mean difference between the wrists of 0.19 m/s (SD = 0.06) and a mean difference between the digits of 0.14 m/s (SD = 0.05). During the bimanual condition this increased to 0.29 m/s (SD = 0.25) at the wrists and decreased to 0.10 m/s (SD = 0.04) at the digits.

VELOCITY CORRELATIONS BETWEEN (INTER) AND WITHIN (INTRA) HAND

Velocity correlations were taken between the wrists and the digits frame by frame, inter (across hands) and intra the hands (within hand) when moving unimanually and bimanually. High correlations are taken as evidence of the limbs working as a coordinated structure both within (intra and (inter) across the hands. (A correlation of less than 0.20 was taken as showing no relation, a correlation of 0.21 – 0.40 as low, a correlation of 0.41 – 0.60 as a moderate relation, and greater than 0.61 as a high relation (see Vereijken *et al.* 1992, Utley and Sugden, 1998; Ko, Challis and Newell, 2003). Across both conditions the coupling between the arms, at both the wrists and the digits, was stronger during the bimanual condition (see table 2). Within hand correlations were moderate or high in all participants for both hands when moving bimanually. The non hemiplegic side produced high correlations intra hand for all participants unimanually and bimanually indicating ‘tight’ control on that side.

GRASP APERTURE

During the unimanual condition, when reaching for the small cube, the hemiplegic hand in all participants tended to have a more gradual closure of the grasp than the non hemiplegic side (see figure 3). During the bimanual condition the hemiplegic side appears to have influenced the movement of the non hemiplegic side with some participants ($N = 6$) demonstrating a gradual closure with both hands in line with the less affected side (see figure 3).

When reaching for the small cube the hemiplegic hand tended to have a larger grasp aperture throughout the movement when moving unimanually and bimanually. Unimanually the mean grasp aperture for the hemiplegic side for all participants was 5.44 cm (SD = 1.12). For the non hemiplegic side the mean grasp aperture was 4.82 cm (SD = 1.03). During the bimanual condition the mean grasp aperture for the hemiplegic side was 5.7 cm (SD = 1.12) and for the non hemiplegic side the mean grasp aperture was 4.53 cm (SD = 0.51).

A different pattern emerged when reaching for the large cube. Across participants the mean grasp aperture during the unimanual movement was 6.47 cm (SD = 1.22) on the non hemiplegic side and 5.92 cm (SD = 1.83) on the hemiplegic side. When moving bimanually the mean grasp aperture was 5.57 (SD = 0.73) on the non hemiplegic side and 6.09 (SD = 1.78) on the hemiplegic side. In four participants the grasp aperture of the hemiplegic hand was greater than that of the non hemiplegic side during the unimanual condition and in four it was less.

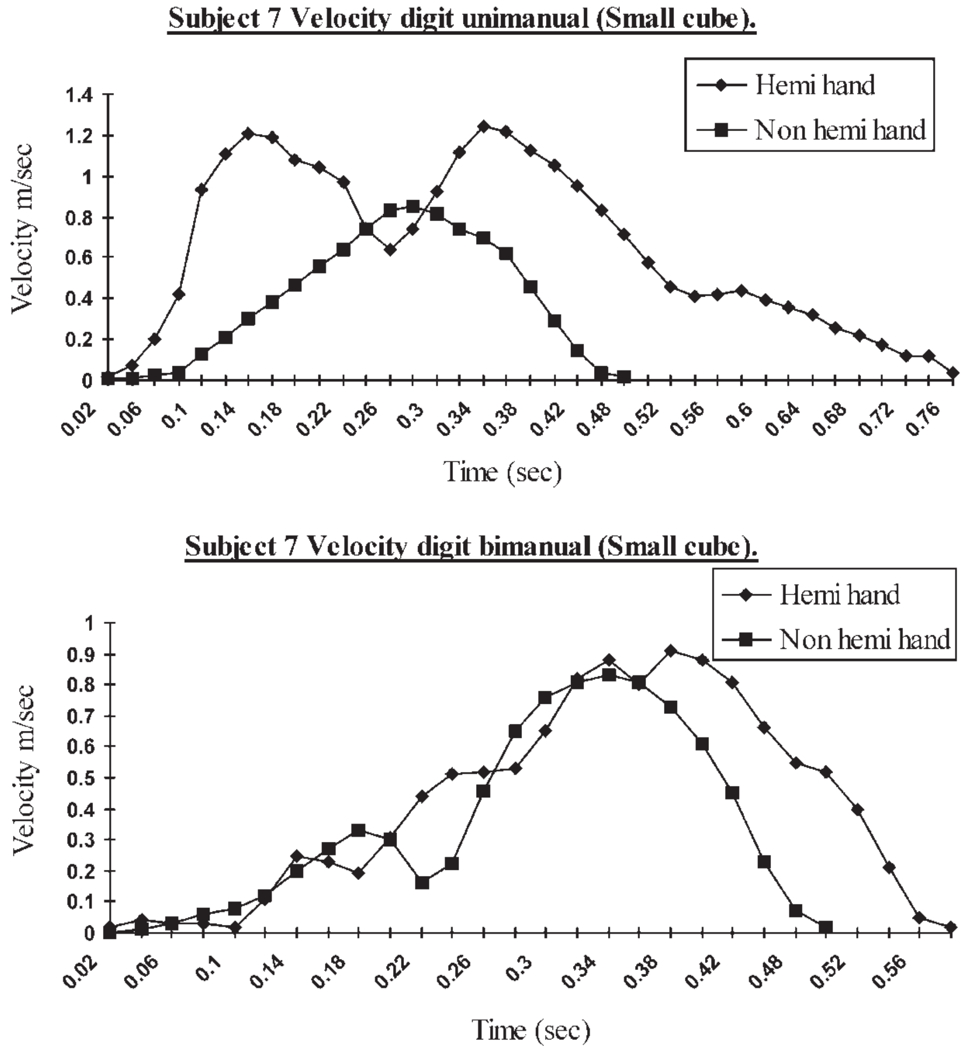
Figure 4 is included as an example of those participants whose hemiplegic hand exhibited a greater aperture during the unimanual condition; while during the bimanual condition there is evidence of coupling, with both hands making adjustments. In some participants there was a rapid increase in grasp aperture during the final third of the movement, which may have been a result of over compensation when grasping a large cube bimanually. Conditions were compared in a 2 (hand: hemiplegic, non-hemiplegic) × 2 (condition: unimanual, bimanual) × 2 (cube: small, large) repeated measures ANOVA design. This analysis revealed that when reaching and grasping bimanually the large cube had a main effect on grasp aperture especially on the non hemiplegic side (F[1,7] = 12.9 $p < 0.01$).

Video data

Observations were made frame by frame of each subject and individual qualitative summaries were made of each subject. An example of these data along with group data on duration of the movement are provided.

Duration of the movement

When moving unimanually the mean difference between the hands was 0.13 s (small cube) and 0.08 s (large cube). During the bimanual movement this decreased to a mean difference of 0.06 s (small cube) and 0.01 s (large cube). This change during the bimanual condition was as a result of the timing of the non hemiplegic hand influencing the movement in some participants, the hemiplegic in others, and both hands



Subject 7 Velocity digit unimanual (Small cube).

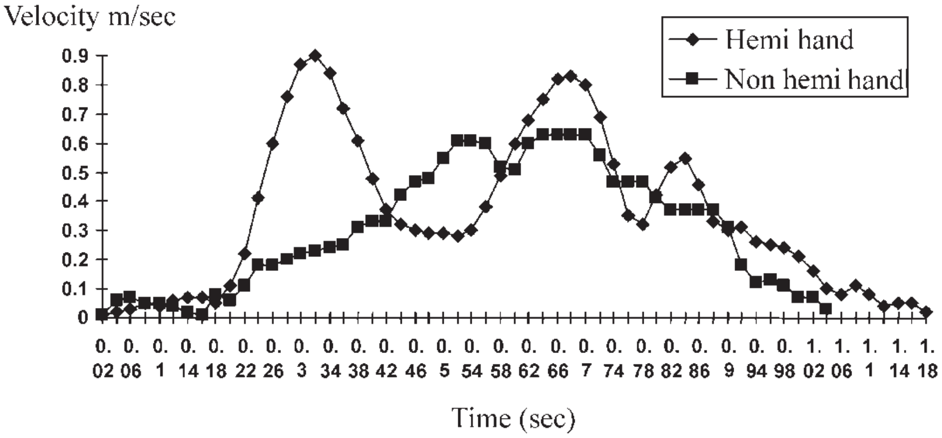
Subject 7 Velocity digit bimanual (Small cube).

Figure 1 Showing the velocity profile (wrist) of subject 7 who has severe hemiplegia on the right side.

making adjustments in other participants. The mean movement duration across all participants was 0.86 s (small cube) and 0.83 s (large cube) for the hemiplegic side and 0.63 s (small cube) and 0.75 s (large cube) on the non hemiplegic side when moving unimanually. During the bimanual condition this decreased to 0.75 s (small cube) and 0.80 s (large cube) on the hemiplegic side and increased to 0.75 s (small cube) and 0.80 s (large cube) on the non hemiplegic side.

Postura and spatial features

When reaching for the small cube participants showed both postural and spatial changes with postural changes being the most significant. Six participants showed changes in the above features and two participants appear to have no postural or spatial changes in the bimanual condition. Four participants showed changes in posture and this generally resulted in the hemiplegic hand showing less splaying and over extension of the digits. In all four participants that showed postural changes it was the non hemiplegic hand which appeared to influence the movement of the hemiplegic hand. Spatial changes resulted in the hemiplegic hand adopting a lower trajectory when moving bimanually. Participants either coupled posturally, spatially, or not at all. The summary in table 3 is included as example of the postural coupling found in this experiment.


Subject 6. Velocity digit unimanual (Large cube).

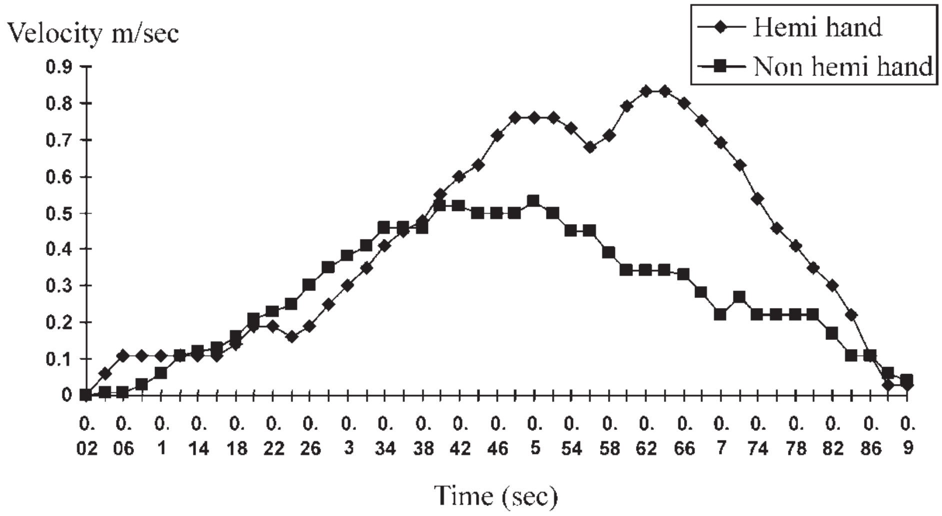

Subject 6. Velocity digit bimanual (Large cube).

Figure 2 Showing the velocity profile (wrist) of subject 6 who has severe hemiplegia on the right side.

The summary in table 3 demonstrates other aspects of the postural coupling seen when reaching for the small cube with the hemiplegic grasp being influenced by the non hemiplegic grasp during the bimanual movement.

When reaching for the large cube there is some evidence of spatial and postural coupling but this is not as strong as in previous experiments.[7] Only two participants coupled spatially with the non hemiplegic hand dominating the movement. Some participants ($N = 4$) showed postural change during the bimanual movement which appeared to assist the grasp of the cube, but this was not as a result of coupling with the non hemiplegic side. Generally, both hands adjusted their posture during the bimanual condition and this appeared to occur independently of the other hand. Some participants ($N = 2$) experienced grasping difficulties on both sides when moving bimanually which had not occurred when moving unimanually.

Table 4 is included as an example of postural and spatial coupling but such coupling did not always improve the function of the reach to grasp during the bimanual condition. In this example, although spatial coupling has taken place, the subject fails to lift the cubes during the bimanual condition.

Discussion

This study provided further evidence on the nature and extent of interlimb coupling in children with hemiplegic cerebral palsy in differing contextual situations. Specifically, we manipulated object size as contextual variable. There is evidence of temporal coupling in both experiments with this tending to be stronger at the digits. As the grasp element of both these experiments was more demanding than that in our previous studies this was not surprising. However, at some time both the hemiplegic and the non hemiplegic hands appear to have dominated temporal coupling during the bimanual condition. Again this reflects the great variability across participants and demonstrates that the nature and extent of coupling varies from subject to subject influenced by contextual factors.

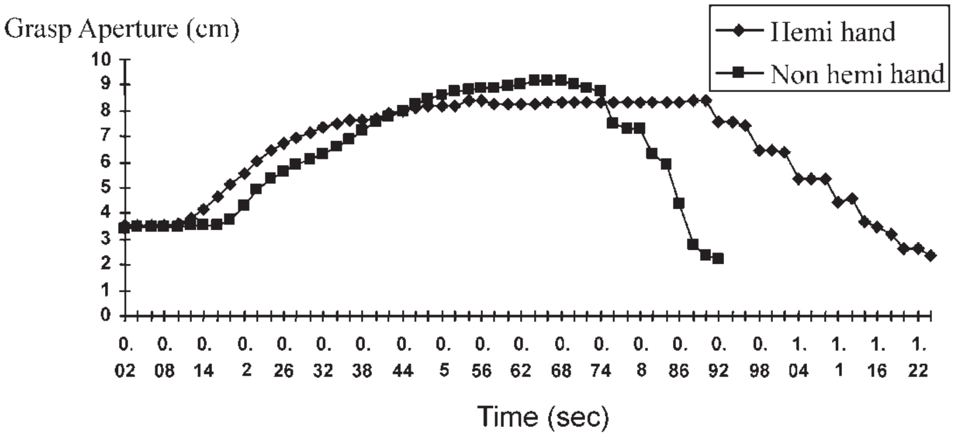
Grasping the small cube resulted in spatial and postural coupling dominated by the non hemiplegic hand. Participants either coupled spatially or posturally and it appears that grasping a small cube has facilitated coupling which has been difficult to influence in our previous work. It may be that a precision grip, which this task afforded, has contextual familiarity in that participants often have to pick up small objects and manipulate them. As a result the 'system' was able to concentrate on this aspect of the movement and moving bimanually enabled hemiplegic features to be reduced by lessening either postural or spatial features seen in the hemiplegic side during the unimanual movement. Thus, when moving bimanually both the transport and the grasp element of the movement were influenced by object size. Grasp aperture data also provided evidence of coupling. The hemiplegic side tended to adopt a wider grasp aperture when moving bimanually and this may well be a coping strategy which assisted the grasping of a small cube. Wing *et al.*[25] and Marteniuk *et al.*[19] reported the widening of grip aperture to cope with more difficult accuracy demands. Eliasson *et al.*[26] discussed the ability of children with cerebral palsy to grip and reported that they have 'impairment in anticipatory control'. This in combination with high accuracy demands may have resulted in the preparation of a wider grip than needed, as a kind of 'safety margin'. When grasping the large cube the results were less conclusive and it would appear that grasping the large cube was too difficult. The maximum grasp aperture for children of this age may well have been reached. Participants adopted many different grasps during the unimanual movement and adjusted them when moving bimanually but this did not appear to occur as a result of the influence of the other hand. As Jeannerod[17, 18] found, changing object size did affect the grasp component.

Table 2 Video analysis summary subject 6 (Small cube)

Subject 6 (AB) Right hemiplegia (Severe)
Unimanual
Hemiplegic side
At the start the hemiplegic limb is held in a 'limp' position. On lift the digits remain limp and are slightly splayed. A medium trajectory is adopted, the digits remain splayed and the hand is slightly supinated. On approaching the cube the hand makes many readjustments and the cube is grasped with the whole hand.
Non hemiplegic side
The non hemiplegic hand is relaxed at the start. A low trajectory is employed with the digits held straight and the thumb extended and abducted. The cube is grasped with the thumb and 1st and 2nd digit in opposition.
Bimanual
The non hemiplegic hand is relaxed at the start and the hemiplegic limb is held in a 'limp' position. On lift the hemiplegic digits remain limp and are slightly splayed the non hemiplegic hand is relaxed with the digits held straight and the thumb extended and abducted. A medium trajectory is adopted by the hemiplegic hand and a low trajectory by the non hemiplegic hand. The non hemiplegic hand reaches the cube first and grasp the cube with the thumb and 1st and 2nd digit in opposition. The hemiplegic hand also grasp the cube with the thumb and 1st and 2nd digit in opposition

Object size has therefore influenced interlimb coupling and the changes seen in the grasp employed from the unimanual to the bimanual condition are especially encouraging. It would appear that the accuracy demand of the task facilitated spatial coupling for some participants and postural coupling for others. Spatial changes resulted in the hemiplegic side adopting a lower trajectory during the bimanual movement. Postural coupling was dominated by the non hemiplegic hand and involved changes in the grasp employed during the bimanual condition by the hemiplegic hand. It would appear that for these participants grasping a small cube has resulted in the grasp component dominating the movement and this has assisted the hemiplegic hand's functional ability in terms of posture. This is significant, as in our previous work[6, 7] posture was identified as the most difficult type of coupling to influence. Spatial changes resulted in the hemiplegic side adopting a lower trajectory during the bimanual movement. Postural coupling was dominated by the non hemiplegic hand and involved changes in the grasp employed during the bimanual condition by the hemiplegic hand. It would appear that for these participants grasping a small cube has resulted in the grasp component dominating the movement and this has assisted the hemiplegic hand's functional ability in terms of posture. As in our previous work[6–8] these findings have implications

Subject 6 Grasp Aperture (cm) unimanual (Small cube).



Subject 6 Grasp Aperture (cm) bimanual (Small1 cube).

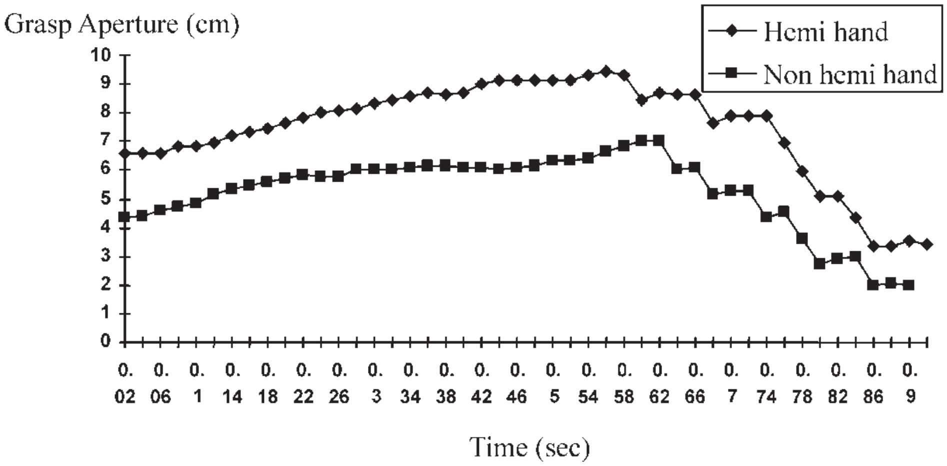
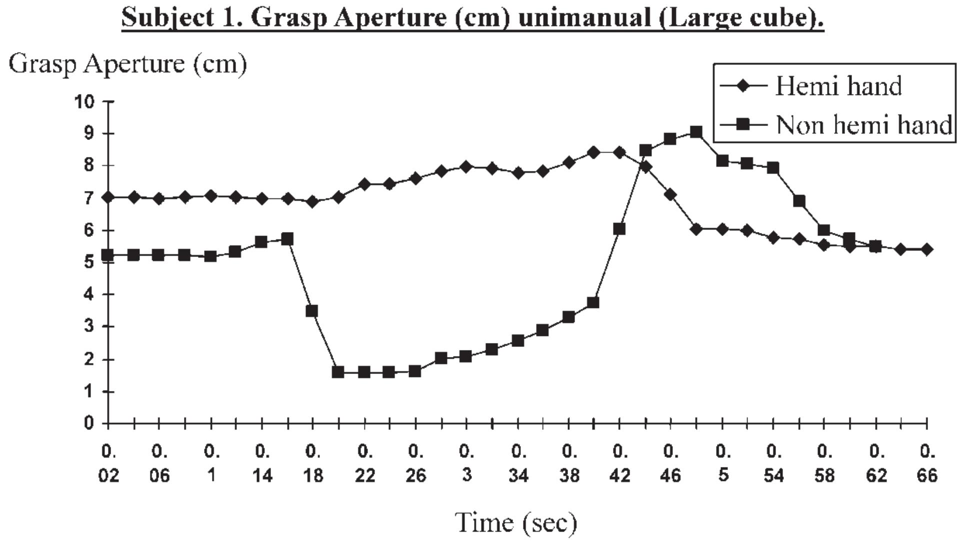


Figure 3 Showing grasp aperture of subject 8 who has mild hemiplegia on the left side.

for therapeutic intervention. The non hemiplegic hand can provide a 'template' for the hemiplegic side when moving bimanually and as a result may lessen some aspect of the hemiplegia observed in the hemiplegic side when moving unimanually (for similar reasoning and experimental proof in drawing see Steenbergen *et al.*[27]). This study also provides further support for our previous findings, which indicate that contextual factors influence the nature and extent of coupling.

The importance of context has been stressed by a number of researchers with the work of Van der Weel *et al.*[13] providing an excellent example of the importance of contextual influence on movement ability. Utley and Sugden[7] have explicitly examined the influence of context on unimanual and bimanual reaching and grasping in children with cerebral palsy. It was found that the nature and degree of coupling across and within participants was greatly influenced by context. Reaching and grasping in differing conditions (speed of movement, slope of board, size of object) had a varying influence on the movement of the hemiplegic side and the non hemiplegic side. Adaptation or learning is influenced by task, environment, and individual constraints. Studies looking at reaching and grasping in children with hemiplegic cerebral palsy provide information about underlying control principles and this must be considered in varying environments with differing tasks. Steenbergen *et al.*[9] and Utley and Sugden[7] have suggested that movement reorganization by participants with cerebral palsy may be adaptive rather than a conse-



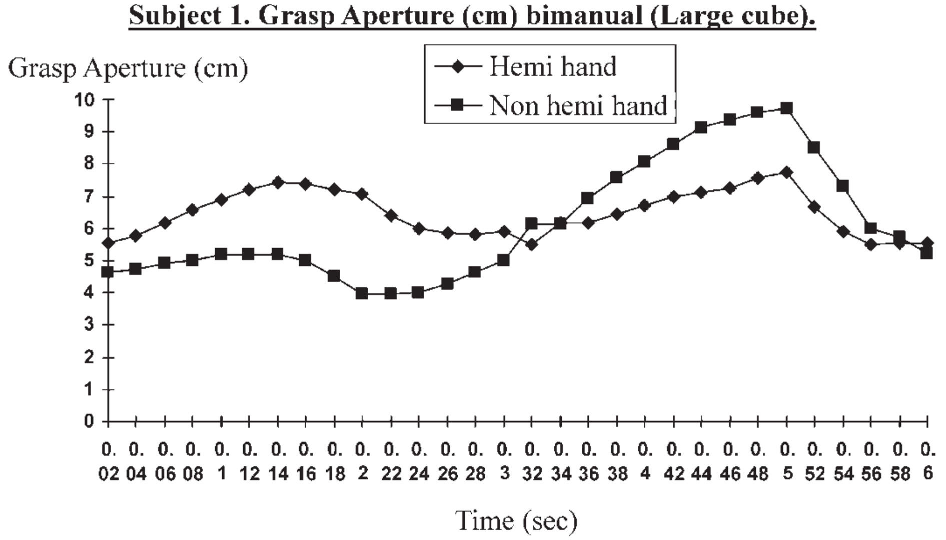


Figure 4 Showing grasp aperture of subject 6 who has severe hemiplegia on the right side.

quence of the disorder (for a discussion on this topic, see Latash and Anson;[29] Steenbergen and Meulenbroek).[28] This adaptability must be considered against task, environment and the individual. It maybe that the results of this study provide evidence for behavioural patterns observed in hemiplegic cerebral palsy been part of an adaptive process.

The therapeutic implications of employing bimanual reaching and grasping have also been considered by Sugden and Utley and Steenbergen *et al*.[7, 8, 30] All of these studies have identified coupling when moving bimanually and have found some influence of the non hemiplegic side on the hemiplegic side. This raises the question as to whether training of the hemiplegic side could occur by repetition of bimanual tasks. In this way the non hemiplegic side would be a template for the hemiplegic side when moving bimanually, with the movement pattern employed bimanually also been employed when moving unimanually.[27] Coupling constraints when reaching bimanually, which appear to be employed by children with hemiplegic cerebral palsy, may prevent movements being selected which

Table 3 Number of high, moderate, low, zero correlations between the wrists and digits (Small cube) for all participants

Condition	*Zero*	*Low*	*Moderate*	*High*
Reach and grasp (Wrists)				
Unimanual	4	0	3	1
Bimanual	0	0	3	5
Reach and grasp (Digits)				
Unimanual	2	3	2	1
Bimanual	0	0	3	5

Table 4 Video analysis summary subject 5 (Large cube)

Subject 5 (AW) right hemiplegia (moderate)

Unimanual

Hemiplegic side

The hemiplegic hand is held in a supinated position at the start with the thumb under the palm and the digits extended. This position is maintained during most of the movement. The arm is very stiff and a medium trajectory is used. On approach to the cube the digits begin to plantar flex. The cube is grasped with the end of the digits. On contact the digits adjust and the hand supinates at the wrist.

Non hemiplegic side

The non hemiplegic hand is held relaxed at the start with the digits extended. The trajectory is low. During the final stages of the approach the thumb is abducted. The cube is grasped with the whole hand.

Bimanual

Hands are relaxed at the start. The non hemiplegic hand lifts three frames before the hemiplegic side. A low trajectory is used by both hands. The digits of the hemiplegic side are extended upwards and splayed, the non hemiplegic digits are splayed and relaxed. This position is maintained throughout. The non hemiplegic hand arrives 3 frames ahead. The whole hand grasps the cubes on the non hemiplegic side and the thumb and 1/2 digits by the hemiplegic side. The cubes are slid back along the table.

inhibit the reach and grasp, especially on the hemiplegic side. Thus, the therapist might be using the natural tendency to couple to assist the function of the hemiplegic side. The acute therapeutic implications of these questions demand further study that includes consideration of individual differences and contextual influences. Finally, the use of multiple recording techniques that were employed in the present study emphasize the need to look at different aspects of coupling to get a better picture of the nature and extent of this coupling.

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