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Full Length Article

End-state comfort planning after explicit goal instructions in children with and without probable developmental coordination disorder

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ABSTRACT

Background: When completing grip-selection tasks, healthy adults generally plan for the most comfortable end-posture which is termed the end-state comfort (ESC) effect. Children with and without developmental coordination disorder (DCD) are less likely to plan for ESC which begs the question as to whether they are not able to perform this type of planning or whether they prioritize other aspects of the task.
Aims: (1) Examine if children with and without probable DCD (pDCD) are able to plan for ESC if they are explicitly instructed to and (2) if this transfers to another similar task. (3) Examine if children with and without pDCD perceive the level of comfort of the grips that they use differently and if this relates to ESC planning.
Methods: Twelve children with and 12 children without probable DCD (pDCD) (aged 5–9 years) received a 10-min training session in which children were explicitly instructed to end their movement in ESC, after which they formulated their own plan to reach this goal. The study consisted of a pre-post-test design in which changes in the proportion of ESC were analyzed on the task that was trained as well as on an untrained transfer-task. Furthermore, the perceived level of comfort was examined.
Results: Both groups of children showed a higher proportion of ESC on the post-test compared with the pre-test, on the task that was trained as well as on the transfer-task. There were no group differences regarding the perceived level of comfort of the different grip postures.
Conclusion: The majority of the children with and without pDCD seems to be able to adjust their planning strategy and prioritize ESC if they are explicitly instructed to.

1. Introduction

The planning of motor actions is an important skill in everyday life. Motor planning has been studied repeatedly in the context of prehension actions using a diversity of grip-selection tasks. In these tasks, the end-state comfort (ESC) effect is often used as an

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indication of motor planning (Rosenbaum et al., 1990). That is, if participants finish a task in a comfortable posture, even if this requires an uncomfortable start-posture, the motor action was planned in advance. While the ESC effect has been demonstrated repeatedly in healthy adults, children are less likely to show the ESC effect which is especially the case for children with motor difficulties such as developmental coordination disorder (DCD) (Wunsch, Henning, Aschersleben, & Weigelt, 2013). This has resulted in the discussion as to whether these children are not able to plan for ESC or whether they prioritize other constraints that afford a different solution, such as the use of the easiest start-posture. The present study was set up to examine to what extent planning for ESC can be trained in children with and without probable DCD (pDCD), by providing explicit instructions regarding the goal of ending the task in a comfortable posture after which children formulated their own plan to reach this goal. In addition, we evaluated their perceived level of comfort in relation to planning for a comfortable start- or end-posture.

The ESC effect is a phenomenon that has been repeatedly demonstrated in healthy adults using varying grip-selection tasks (Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012). Compared with adults, typically developing (TD) children are less likely to show the ESC effect (Wunsch et al., 2013). Children with DCD seem to be even less likely to plan for ESC (Adams, Lust, Wilson, & Steenbergen, 2014). Importantly, in previous studies that focused on the ESC effect, ending the task in a comfortable posture was never made an explicit goal (Adams et al., 2014; Bhoyroo, Hands, Steenbergen, & Wigley, 2019). Because most researched tasks can also be relatively easily completed with an uncomfortable end-posture, children with and without DCD may very well prioritize other aspects of the task than adults do (Bhoyroo, Hands, Wilmut, Hyde, & Wigley, 2018; Wilmut & Byrne, 2014). It can thus be questioned whether children with and without DCD would be able to change their planning strategy and prioritize ESC if they are explicitly instructed to do so. If it turns out that children are indeed able to change their strategy, this would suggest that children prioritize other task aspects rather than that they are not able to plan their movements in advance successfully.

The use of more elaborate instructions on the completion of grip-selection tasks has been studied before (Bhoyroo, Hands, Wilmut, Hyde, & Wigley, 2019). The study of Bhoyroo, Hands, Wilmut, et al. (2019) focused on the question whether motor imagery could be a strategy for increasing ESC planning in children with and without DCD. Children with and without DCD completed a grip-selection task under two conditions. In the first condition, children were only instructed to grasp and rotate a pointer to (a) named colour(s). In the second condition, children were instructed to first imagine how they would grasp and rotate the pointer before performing the action. It was found that both, children with and without DCD used the ESC strategy more often after they had received the motor imagery instructions. These results provide evidence that ESC planning can be altered in children with and without DCD. Importantly however, also with these motor imagery instructions, the goal of ending the task in a comfortable posture was not made explicit. Therefore, children for whom prioritizing ESC is not the most optimal planning strategy probably will not adjust their strategy after motor imagery instructions.

The instructions used in the present study are based on the Cognitive Orientation to daily Occupational Performance (CO-OP) approach (Polatajko, Mandich, Miller, & Macnab, 2001). CO-OP is one of the recommended task-specific interventions for treatment in children with DCD (Blank et al., 2019). The CO-OP approach uses a global problem-solving strategy (i.e., *goal, plan, do check*). In addition, children learn to use domain specific strategies that are task and situation specific. It enables children to analyze whether their performance was successful and to devise and carry out plans to correct themselves if necessary. Thus, within the CO-OP approach, children are stimulated to explicitly formulate a plan to improve their motor skill. In the present study, the goal of ending the movement in a comfortable end-posture was made explicit to the children. Using the CO-OP approach, children were stimulated to make their own plan in order to achieve this goal.

Whilst CO-OP is a task-specific approach, it is assumed that the use of cognitive strategies also supports the transfer of learned strategies (Polatajko et al., 2001). The transfer of motor skills refers to the application of a learned skill in a new task or context and is an important aspect of motor learning (Schmidt & Lee, 2011). In general, it seems that children with DCD are able to engage in effective motor learning that is sufficient to ensure transfer, even though they may be slower and need more practice than TD children (Biotteau, Chaix, & Albaret, 2016, for a review).

What is considered to be a comfortable or an uncomfortable end-posture in previous research has always been judged from an adults' perspective, but children with and without DCD may experience this differently (Rosenbaum, Herbort, Van Der Wel, & Weiss, 2014). If children do not experience the same level of discomfort as adults when completing tasks in an "uncomfortable" posture, this may explain why they are less likely to prioritize ESC. In individuals with cerebral palsy (CP) (aged 14–19 years) it was shown before that the perceived comfort of the different end-postures varies and that not all participants rated the ESC posture as least awkward (Steenbergen, Hulstijn, & Dortmans, 2000). If this is also the case for children with and without DCD, these children will be less likely to prioritize an uncomfortable start-posture in order to end the task with a "comfortable" posture. To test this suggestion, we included children's perceived level of comfort with regard to the varying start- and end-postures in the present study.

In conclusion, under the assumption that children with and without DCD may prioritize aspects of the motor task that are different from ESC, we explicitly instructed them to adhere to ending in ESC. The first aim of the study was to examine if planning for ESC could be increased in children with and without pDCD by providing explicit goal instructions that were based on the CO-OP approach. We hypothesized that both children with and without pDCD would be able to prioritize ESC if they are explicitly instructed to do so. The second aim was to examine whether this training effect would transfer to another similar task. Since CO-OP supports transfer of learning, we hypothesized that both children with and without pDCD would show improvement in their ESC planning score on a transfer-task as well. Third, we examined group differences in the perceived level of comfort of different grips and hypothesized that children with pDCD would perceive less difference between "comfortable" and "uncomfortable" grips than TD children. Additionally, we explored the relation between the perceived level of comfort and the ESC planning scores. Twelve children with pDCD and 12 TD children (aged 5 to 9 years) received a short training session (based on the CO-OP approach principles) using the previously used sword task (e.g., Crajé, Aarts, Nijhuis-van der Sanden, & Steenbergen, 2010) or a new custom-made magic wand task (Fig. 1). The latter was designed such that it was similar to the sword-task with regards to task demands.

2. Method

2.1. Participants

Child characteristics are presented in Table 1. Twelve children with pDCD participated in the present study. Six additional children with pDCD participated but were not included in the data analysis of the present study because they had difficulties to complete the experimental tasks ($n = 1$) or because they had a maximum score (i.e., ended all trials in a comfortable end-posture) on the pre-test measure such that training was not necessary ($n = 5$). Children with pDCD were recruited through a pediatric exercise therapist. The inclusion criteria for the pDCD group were defined based on the Diagnostics and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013). Children had a Movement Assessment Battery for Children 2 (MABC-2; Henderson, Sugden, & Barnett, 2007; Smits-Engelsman, 2010) total percentile score ≤ 16th or any of the three component percentile score ≤ 5th (criterion A), were treated or had been treated for a motor coordination problem by a pediatric physical/exercise therapist (criterion B), were aged 5–9 years (criterion C), and parents reported no cognitive impairment, visual impairment, or neurological deficit that would explain the child's motor difficulties (criterion D). In the absence of a full clinical assessment, we refer to this group as pDCD.

In addition, 12 sex and age-matched (within 6 months, except for two children that were matched within 7 and 8 months, respectively) TD controls participated. Here, four additional children participated but were excluded from further analyses because they were not a suitable match for one of the pDCD children ($n = 1$) or because they had the maximum score on the pre-test measure ($n = 3$). Children in the control group were recruited in three mainstream primary schools. All TD children had a MABC-2 total percentile score > 16th.

Parents were asked to complete four questionnaires to gain insight into the sample characteristics: a DCD questionnaire as a descriptive measure of DCD symptoms (DCD-Q'07, Dutch translation CVO; Schoemaker, Reinders-Messelink, & de Kloet, 2008), the DCDDaily-Q as a measure of the interference of motor difficulties with activities of daily living (van der Linde, van Netten, & Schoemaker, 2015), an ADHD-questionnaire as a descriptive measure of attention deficit hyperactivity disorder (ADHD) symptoms (AVL; Scholte & van der Ploeg, 2004) and a Social Behaviour Questionnaire as a descriptive measure of autism spectrum disorder (ASD) symptoms (VISK; Hartman, Luteijn, Moorlag-Jonger, Minderaa, & De Bildt, 2014). The study was approved by the Ethics Committee of the Faculty of Social Sciences at the Radboud University (ECSW-2020-162).

2.2. Materials

2.2.1. Motor planning

Motor planning was measured with the previously used sword-task (Crajé et al., 2010) and the new custom-made magic-wand-task (depicted in Fig. 1). In the sword-task, children are instructed to pick up the sword with their dominant hand using a whole-hand grip and to subsequently stick it into the hole of the wooden block. The magic-wand-task was developed to match the task demands of the

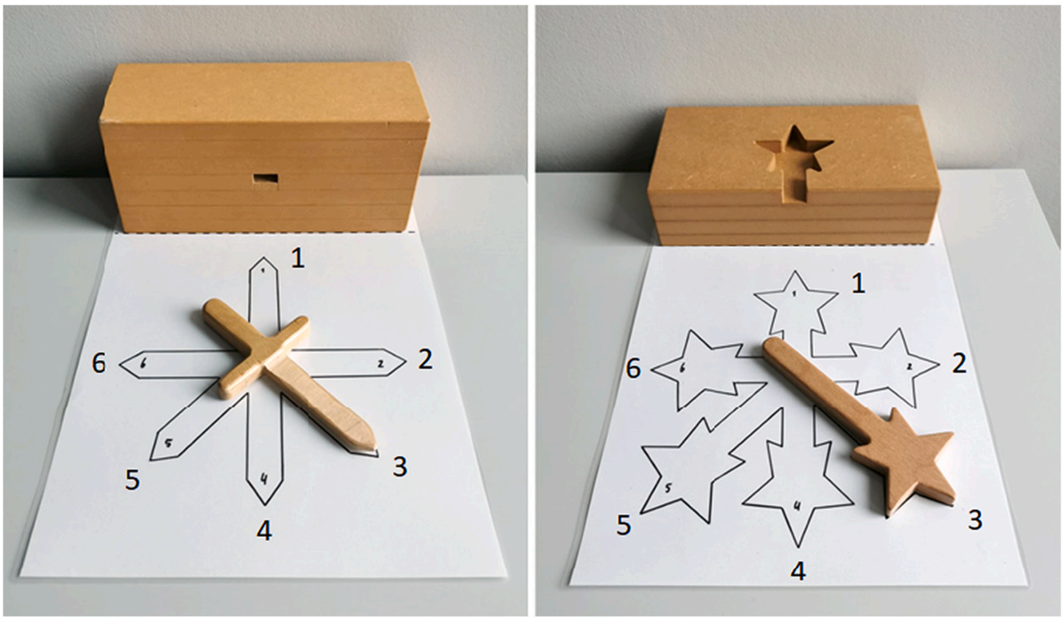

Fig. 1. Sword-task on the left and magic-wand-task on the right, with the sword/magic-wand in orientation 3.

Table 1
Child characteristics for the pDCD group and TD group.

	pDCD group (n = 12)	TD group (n = 12)
Age in years *M* (*SD*)	7y3m (1y0m)	7y2m (0y11m)
Sex (males/females) *n*	10/2	10/2
Dominant hand (left/right) *n*	3/9	4/8
MABC-2 total score in percentiles *M* (*SD*)	6.80 (6.28)	41.58 (12.43)
DCD-Q'07 total sum score *M* (*SD*)	61.82 (5.58) $^{n=11}$	60.00 (9.41) $^{n=12}$
DCDDaily-Q participation *M* (*SD*)	36.27 (9.13) $^{n=10}$	33.57 (5.07) $^{n=11}$
DCDDaily-Q quality *M* (*SD*)	32.20 (5.98) $^{n=10}$	32.45 (5.99) $^{n=11}$
DCDDaily-Q learning *M* (*SD*)	3.50 (2.55) $^{n=10}$	2.82 (3.34) $^{n=11}$
AVL total sum score *M* (*SD*)	23.00 (13.45) $^{n=11}$	20.05 (12.92) $^{n=11}$
VISK total sum score *M* (*SD*)	20.60 (9.24) $^{n=10}$	14.64 (7.75) $^{n=11}$

Note. MABC-2, Movement Assessment Battery for Children 2; DCD-Q'07; developmental coordination disorder questionnaire, score can theoretically vary between 15 and 75 with lower scores indicating more symptoms; DCDDaily-Q, questionnaire focusing on difficulties in activities of daily living, scores on subscales participation, quality, and learning can theoretically vary between 23 and 92, 23 and 69, and 0 and 23, respectively, with higher scores indicating more difficulties; AVL, attention-deficit/hyperactivity disorder questionnaire, score can theoretically vary between 0 and 72 with higher scores indicating more symptoms; VISK, autism spectrum disorder questionnaire, score can theoretically vary between 0 and 98 with higher scores indicating more symptoms. The number of children for whom each questionnaire was completed is indicated using superscript.

sword-task. In the magic-wand-task, children needed to pick up the magic-wand and put it into the mold of the wooden block. Each trial the experimenter placed the sword/magic-wand on a template board with six possible orientations. Two orientations served as critical orientations (i.e., orientation 2 and 3 for right-handers and orientation 5 and 6 for left-handers). In the critical orientations, children needed to sacrifice comfort of their start-posture to end the task in a comfortable posture (i.e., critical trials). All trials were repeated three times, resulting in a total of 18 trials per task. A score of 1 (i.e., action ended in ESC with the thumb towards the blade/star) or 0 (i.e., action did not end in ESC, with the thumb away from the blade/star) was assigned for each trial. In case children changed their grip during the movement by rotating the sword or magic-wand in their hand, they received feedback that they were not allowed to change their grip during the movement and the trial was repeated by the experimenter. In case children corrected their own grip before ending the movement by placing back the object and restarting the trial by themselves, the latter grip was used for scoring. The proportion of ESC in the critical and non-critical orientations was used as the outcome measure.

2.2.2. Perceived level of comfort

Children were asked to rate the perceived level of comfort of the two possible grips that could be used (i.e., with the thumb towards or with the thumb away from the blade/star) in the end-orientation and all start-orientations. The task that was used for this measure (i.e., sword-task or magic-wand-task) was the same task that was used for the training afterwards and was balanced across subjects. The rating was done on a five-point scale: very uncomfortable (1), uncomfortable (2), not uncomfortable/not comfortable (3), comfortable (4), or very comfortable (5). Children answered by pointing out the number on a scale with smileys. For the end-posture, the ESC-posture refers to a grip with the thumb towards the blade/star and the non-ESC-posture refers to a grip with the thumb away from the blade/star. For the start-posture in the critical orientations, the start-state comfort posture (SSC-posture) refers to a grip with the thumb away from the blade/star and non-SSC-posture refers to a grip with the thumb towards the blade/star. For the non-critical orientations, the SSC-posture refers to a grip with the thumb towards the blade/star and non-SSC-posture refers to a grip with the thumb away from the blade/star. The experimenter made sure the arm and hand of the child were in the right posture by providing instructions or by modelling it. The child rated the static posture. The two possible grips in the end-orientation and all start-orientations were rated once.

2.3. Training session

The training session was based on the CO-OP approach (Polatajko et al., 2001). Four cards with the words of the global problem solving strategy (i.e., *goal, plan, do check*) were used as visual support. The first aim of the training session was to make the goal of ending the motor planning task in ESC explicit. Children were asked to hold the sword or the magic-wand in front of them and to tell the experimenter what grip (i.e., with the thumb towards or away from the blade/star) they perceived as more comfortable/convenient. If children reported that they found the ESC-posture to be more comfortable/convenient, the training session proceeded. If children reported that they found the non-ESC posture to be more comfortable/convenient or if they did not feel a difference, they were asked to imagine to fight a dragon or make a graceful movement conjuring a spell. In doing so, it was explained to them that the ESC-posture would be more convenient for these movements. Children were then instructed to always end the movement in that way while the experimenter demonstrated the grip. After the child was instructed that the explicit goal of the task was to always end in ESC (*goal*), the child had to invent a plan to achieve the task goal (*plan*). The child then tried the planned strategy (*do*) and evaluated how well the plan worked (*check*) after each trial. The child used his or her own words when formulating the plan. When a plan did not result in ESC, the child had to propose a new plan until it succeeded. The training session was terminated in case the child demonstrated ESC on all six orientations three times in a row or when 10 min had passed.

2.4. Procedure

The study was conducted at the children's school and took place in a quiet room. The study consisted of two sessions of about 30 min. In the first session, the MABC-2 was assessed. The second session started by completing the two motor planning tasks (i.e., pre-test). The order of the sword-task and magic-wand-task was counterbalanced. Directly after the pre-test, the perceived level of comfort was assessed. In case children ended less than 100% of the trials in ESC on at least one of the tasks, children were included in the training group. If children ended 100% of the trials in ESC on both tasks on the pre-test measure, children were not trained and played a game (i.e., Jenga) for about 10 min instead (5 pDCD, 3 TD). The training group received a CO-OP based training session using either the sword-task or the magic-wand-task (balanced across subjects). After the training session (or playing the game), children completed the two motor planning tasks again (i.e., post-test). The post-test started with the task that was trained (i.e., "trained-task") to measure the training-effect, after which the other task (i.e., "transfer-task") was examined to measure the transfer-effect.

2.5. Analyses

2.5.1. Effects of explicit goal instructions

In the Supplementary material, results can be found for the sword-task and magic-wand-task separately including a comparison of the performance on both tasks. As expected, moderate to high correlations were found between the pre-test scores of the two tasks. Given these results and the fact that a counterbalanced design was applied, it was assumed that the type of task that was trained did not impact the results. It was therefore decided to analyze the effects of the explicit goal instructions for the trained-task and transfer-task.

To analyze whether performance changed from pre-test to post-test on the trained-task and on the transfer-task for children with pDCD and TD children, two generalized linear mixed-effects models were performed with a binomial link function using the glmer function of the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) in R (R Core Team, 2020). In the models, performance (proportion of ESC on the critical orientations, included as the number of critical trials ending in ESC and the number of critical trials not ending in ESC) was predicted as a function of the fixed effect of group (pDCD or TD), the fixed effect of measurement time (pre-test or post-test), as well as the interaction between these two predictors. A random intercept for participant was included in order to control for individual variances across measurements. The model was conducted separately for the trained-task and for the transfer-task. Values of p are based on confidence intervals (CIs) and the beta coefficients that resulted from the model were converted into odds ratios (ORs). Follow-up analyses consisted of simplified versions of the same model. All models ran without warnings and model diagnostic plots yielded no indication of strong violations of assumptions.

2.5.2. Perceived level of comfort

There was one child in the TD group for whom the data on the perceived level of comfort was missing. This child was excluded from the following analyses. To analyze if there were differences between the pDCD and TD group in the perceived level of comfort of the ESC-posture and non-ESC-posture and the average SSC-posture and non-SSC-posture in the critical orientations, Mann-Whitney U tests were performed. In addition, to examine whether children experienced differences in the perceived level of comfort of the ESC-posture and non-ESC-posture and the SSC-posture and non-SSC-posture in the critical orientations, Wilcoxon signed-rank tests were performed. Finally, it was determined whether the perceived level of comfort was related to the performance on the sword-task and magic-wand-task during pre-test. In order to do this, a new variable was calculated using the following formula: (rating ESC – rating non-ESC) - (rating SSC critical orientations – rating non-SSC critical orientations). This variable represents the profit of finishing in a comfortable end-posture relative to the profit of starting in a comfortable posture. A score above 0 indicates a higher experienced profit of ESC compared with SSC and a score below 0 indicates a higher experienced profit of SSC compared with ESC (the score can theoretically vary between −8 and 8). The correlation between this variable and the average proportion of ESC on the critical trials of the pre-test of the sword-task and magic-wand was calculated using Spearman's rho. A positive correlation would indicate that children who experience more profit of ESC compared with SSC demonstrated a higher proportion of ESC on the pre-test of the tasks.

Table 2
Proportion of ESC on the critical and non-critical trials of the trained-task and transfer-task.

			pDCD group			TD group		
			M	*SD*	*Mdn*	*M*	*SD*	*Mdn*
Trained task	Critical trials	Pre-test	0.32	0.25	0.33	0.35	0.40	0.17
		Post-test	0.88	0.14	0.92	0.76	0.32	0.83
	Non-critical trials	Pre-test	0.92	0.13	1.00	0.97	0.06	1.00
		Post-test	0.97	0.05	1.00	0.94	0.15	1.00
Transfer task	Critical trials	Pre-test	0.40	0.26	0.42	0.33	0.41	0.08
		Post-test	0.75	0.34	0.83	0.83	0.39	1.00
	Non-critical trials	Pre-test	0.96	0.08	1.00	0.97	0.04	1.00
		Post-test	0.99	0.03	1.00	0.96	0.07	1.00

3. Results

3.1. Effects of explicit goal instructions

Descriptive statistics of the critical and the non-critical trials of the trained-task and the transfer-task are presented in Table 2. Individual data of the critical trials are presented in Fig. 2.

When looking at the trained-task, 11 children with pDCD performed better on the post-test compared with the pre-test and one child had equal scores. In the TD group, eight children improved their scores, one child had equal scores, and three children had a

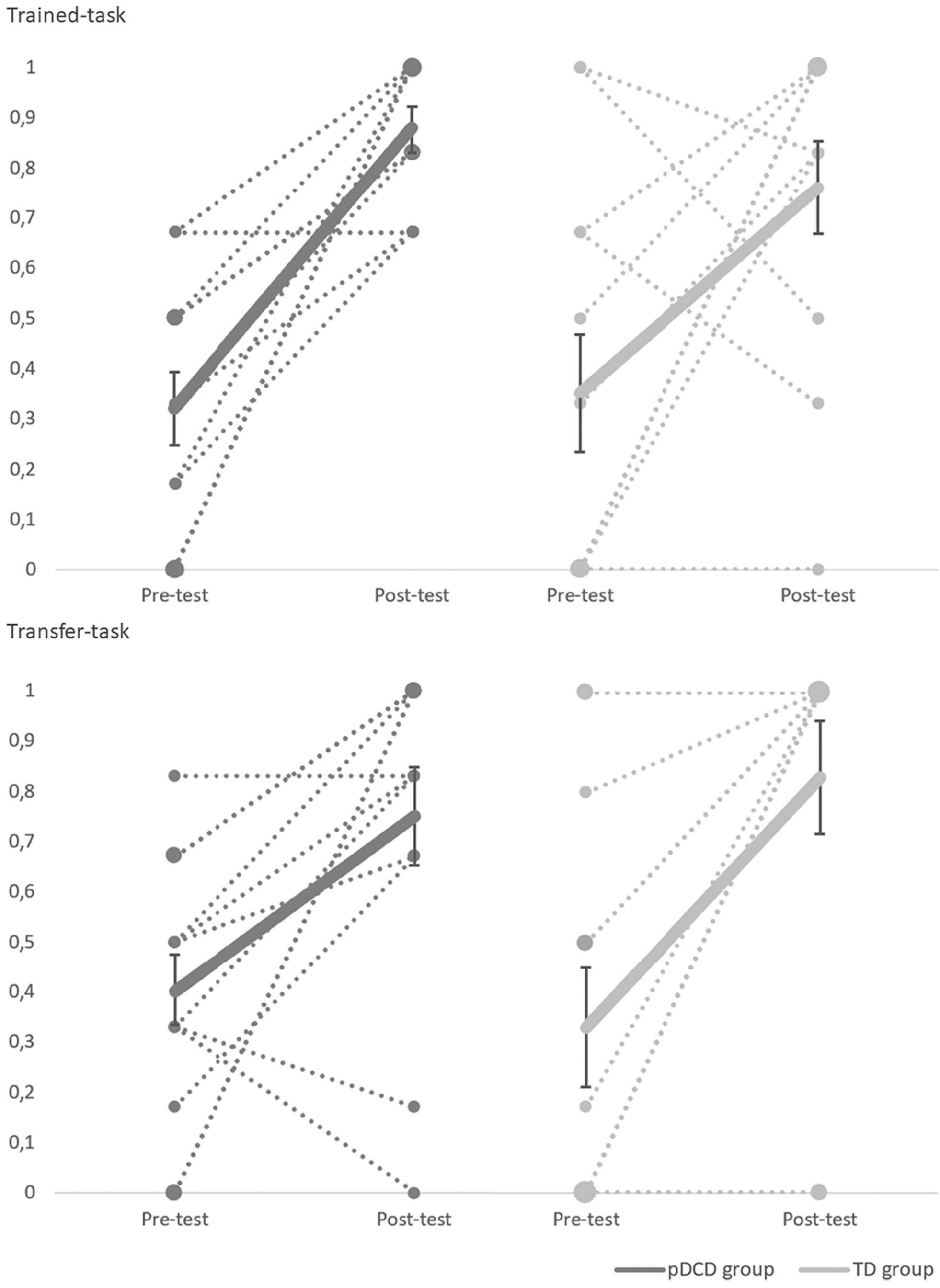

Fig. 2. Proportion of end-state comfort (ESC) on the critical trials of the trained-task and transfer-task with children with probable developmental coordination disorder (pDCD) on the left and typically developing (TD) children on the right. Dotted lines represent individual children with the diameter of the caps being proportional to the number of individuals. The bold lines represent the group average and error bars represent SEs.

lower score on the post-test compared with the pre-test. Results of the model including the trained-task showed a statistically significant effect of measurement time, indicating that the average proportion of ESC was higher on the post-test compared with the pre-test, $OR = 3.59$, $b = 1.28$, $SE = 0.16$, $z = 7.80$, $p < .05$, 95% CI [0.97, 1.65]. The main effect of group, $OR = 1.21$, $b = 0.19$, $SE = 0.22$, $z = 0.86$, $p > .05$, 95% CI [−2.33, 0.70], and the interaction between measurement time and group, $OR = 1.22$, $b = 0.20$, $SE = 0.15$, $z = 1.28$, $p > .05$, 95% CI [−0.10, 0.55], were not statistically significant. This indicates that the increase in scores on the trained-task was not statistically different between children with pDCD and TD children.

When considering the transfer-task, in the pDCD group, nine children performed better on the post-test compared with the pre-test, one child had equal scores, and two children had a lower score on the post-test compared with the pre-test. In the TD group, eight children improved their scores and four children had equal scores. Results of the model including the transfer-task showed a statistically significant effect of the interaction between measurement time and group, $OR = 0.36$, $b = -1.03$, $SE = 0.38$, $z = -2.72$, $p < .05$, 95% CI [−2.40, −0.48]. To follow-up on this significant interaction, two additional models were performed for the pDCD and TD group separately. Here it was found that the effect of measurement time was statistically significant for both the pDCD group, $OR = 2.43$, $b = 0.89$, $SE = 0.21$, $z = 4.30$, $p < .05$, 95% CI [0.50, 1.33], and the TD group, $OR = 4018.46$, $b = 8.30$, $SE = 2.44$, $z = 3.40$, $p < .05$, 95% CI [3.73, 14.35]. This indicates that both children with pDCD and TD children had a higher score on the post-test compared with the pre-test. The significant interaction suggests that the increase in scores on the transfer-task may be somewhat higher for TD children as compared with children with pDCD.

3.2. Perceived level of comfort

An overview of the perceived level of comfort ratings is presented in Table 3. First, there were no statistically significant differences between the pDCD and TD group in the perceived level of comfort of the ESC-posture, $U = 43.50$, $Z = -1.44$, $p = .149$, and the non-ESC-posture, $U = 57.00$, $Z = -0.57$, $p = .569$. Furthermore, there were no statistically significant differences between the two groups with regard to the perceived level of comfort of the average SSC-posture of the critical orientations, $U = 54.00$, $Z = -0.75$, $p = .453$, and the average non-SSC-posture of the critical orientations, $U = 47.50$, $Z = -1.15$, $p = .249$.

Second, differences in the perceived level of comfort between the types of grips were examined. Overall, there was no statically significant difference in the perceived level of comfort of the ESC-posture and the non-ESC-posture, $Z = -1.39$, $p = .165$. With regard to the average SSC-postures and the average non-SSC-postures of the critical orientations, the difference in perceived level of comfort was statistically significant, $Z = -3.74$, $p < .001$. This indicates that children experience differences between the “uncomfortable” and “comfortable” start-posture, while they do not experience significant differences between the two end-postures.

Third, it was determined whether the perceived level of comfort was related to the performance on the tasks. The relation is visualized in Fig. 3. Results showed that there was no statistically significant correlation ($rho = -0.10$, $p = .661$) between the perceived level of comfort of the end-posture relative to the start-posture and the performance on the motor planning tasks during pre-test.

4. Discussion

The main aim of this study was to investigate whether the prioritization of ESC in a motor planning task can be increased using explicit goal instructions based on the CO-OP approach in children with and without pDCD. Children received a short training session using the sword-task or the newly developed magic-wand-task. Contrary to previous research in grip-selection tasks, the goal of ending the task with a comfortable end-posture was explicitly instructed during the training session after which children formulated their own plan to reach this goal. We found that both children with pDCD and TD children showed increased use of grips resulting in ESC. This was found on the task that was trained as well as on the transfer-task. In addition, we examined whether children with and without pDCD perceive the level of comfort of the possible start- and end-postures differently. We found no differences between the two groups of children with regard to the perceived level of comfort. Furthermore, the results suggest that children experienced a stronger difference in the perceived level of comfort between the two start-postures compared with the end-postures. The perceived level of comfort was not related to the actual performance (i.e., proportion of ESC) on the tasks in our study. Below we first discuss the effects of the explicit goal instructions on motor planning which is followed by a discussion of the results on the perceived level of comfort.

Table 3
Overview of the perceived level of comfort of the different end-postures and start-postures for the pDCD and TD group separately.

		pDCD group			TD group		
		M	*SD*	*Mdn*	*M*	*SD*	*Mdn*
End orientation	ESC-posture	3.50	1.17	4.00	4.09	1.30	5.00
	Non-ESC-posture	3.00	1.60	3.00	3.36	1.29	3.00
Start average critical orientations	SSC-posture	3.63	1.26	4.00	4.09	0.83	4.00
	Non-SSC-posture	2.08	1.14	1.50	2.50	0.59	2.50
Start average non-critical orientations	SSC-posture	3.65	0.60	3.50	4.14	0.63	4.25
	Non-SSC-posture	2.48	0.95	2.50	2.82	1.07	2.75

Note. ESC = end-state comfort; SSC = start-state comfort. Start critical orientations include the average rating of orientations 2 and 3 for right-handed children and orientations 5 and 6 for left-handed children. Non-critical orientations include the average rating of orientations 1, 4, 5, and 6 for right-handed children and orientations 1, 2, 3, and 4 for left-handed children.

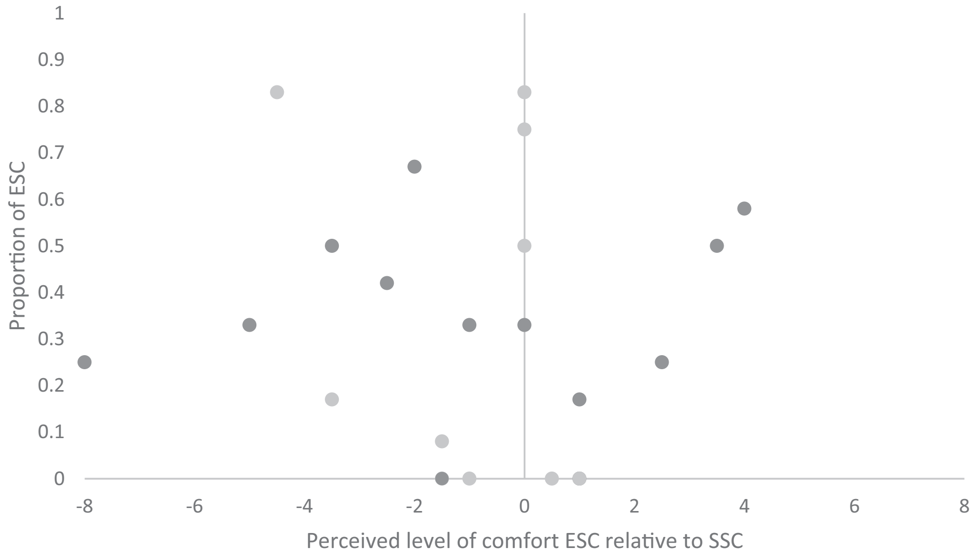

Fig. 3. Relationship between the perceived level of comfort of the ESC-posture relative to the SSC-posture and the proportion of end-state comfort (ESC) in the critical trials of the sword-task and magic-wand-task during pre-test, for children with probable developmental coordination disorder (dark grey) and typically developing children (light grey).

In line with our expectations, the majority of the children with as well as without pDCD (19 out of 24 children) ended the task more often in a comfortable posture after the short training session. During this training session, children were made aware of the goal of ending the task in a comfortable posture. Following the global problem-solving strategy of the CO-OP approach, children then formulated their own plan to achieve this goal after which they tried and evaluated the plan. Following training, children completed the task that was trained again as well as an untrained transfer-task with similar task demands. We found that the explicit goal instructions and the use of the global problem-solving strategy of the CO-OP approach led to more frequent planning according to ESC, both on the trained-task as well as on the transfer-task. The majority of the children were thus able to make use of anticipatory planning in which comfort of the start-posture was sacrificed such that the task was ended in a comfortable posture if they were explicitly instructed to do so. This alteration in motor planning and prioritization of ESC is in line with previous research in which children received motor imagery instructions before completing the motor planning task (Bhoyroo, Hands, Wilmut, et al., 2019). The increase in proportion of ESC on the transfer-task seemed to be somewhat higher for TD children compared with children with pDCD. This is in line with the study of Biotteau et al. (2016) in which it was concluded that children with DCD are able to apply learned skills in a new task, but that they may be slower than TD children. It is important to note here that this result and conclusion needs to be interpreted with caution given the small sample size of the study.

Our findings thus suggest that when children know what the explicit aim of the task is, the majority of the children are able to change their strategy and adjust their grip accordingly. These results are in agreement with the hypothesis that children with and without pDCD generally employ alternative motor planning strategies rather than that they are not able to take into account the end-state of a movement (Bhoyroo et al., 2018; Krajenbrink, Lust, & Steenbergen, 2021; Wilmut & Byrne, 2014). The few occasions in which children initially grasped the sword or the magic-wand with a comfortable grip, then rotated the object and noticed that they were going to end in "the wrong" way, and then quickly placed the object back and adjusted their grip according to ESC, are also in line with this hypothesis. It could indicate that these children just learned a "trick" and performed the tasks in the way that they were instructed to in the training, but did not internalize prioritization of ESC as a new motor planning strategy. It could also reflect that it was difficult for them to mentally simulate their movement upfront. They may have needed the visual and sensory feedback of the movement in order to correct themselves during the trial. Previous research showed that the ability to use motor imagery develops between the ages of 5 and 12 years (Spruijt, van der Kamp, & Steenbergen, 2015). For future research, it would be interesting to examine motor imagery as well and to find out whether this ability is related to the use of ESC planning after explicit goal instructions.

Contrary to our expectations, there were no (initial) differences between children with and without pDCD in the proportion of ESC planning. This is in contrast to previous research that used the sword-task and showed that children with DCD ended their movements less often in a comfortable posture compared with TD children (e.g., Adams, Lust, Wilson, & Steenbergen, 2017; Krajenbrink, Lust, Beckers, & Steenbergen, 2021). The lack of difference between the two groups in the present study is most likely due to the fact that the DCD symptoms of the children in our sample were relatively mild. Children in the pDCD group scored at or below the 16th percentile of the MABC-2 and had been treated for a motor coordination problem by a pediatric exercise therapist, but the results of the questionnaires that parents completed did not differ between the two groups. It has been previously suggested that the severity of DCD symptoms could explain why in some studies there were no differences in ESC planning scores between children with and without DCD (Adams, Ferguson, Lust, Steenbergen, & Smits-Engelsman, 2016). For future research it is therefore warranted that a clinical sample is included in order to verify if these children would benefit in a similar fashion from explicit goal instructions.

The third aim of the study was to examine whether children with and without pDCD perceived the level of comfort of the possible grip postures differently and whether this was related to their performance on the tasks. We did not find any differences between children with and without pDCD with respect to their perceived level of comfort of the different grip postures. In line with previous research in individuals with CP (Steenbergen et al., 2000), we did find that the difference in the perceived level of comfort between the "uncomfortable" and "comfortable" grips was larger for the start-postures in the critical orientations compared with the end-postures, for both groups of children. On average, children rated the start-grip that is necessary in the critical orientations to reach ESC as uncomfortable, while the non-ESC-posture was not necessarily perceived as uncomfortable in both groups. If the costs of a difficult initial grip are higher than the benefits of ending in ESC, prioritizing ESC is likely not the most efficient motor planning strategy. This could explain why children generally use the easiest initial posture. Still, we did not find a significant relation between the individual level of comfort judgements and the actual performance on the task. In our sample, there were only six children for whom the benefits of ending in ESC were higher than the costs of starting in non-SSC, limiting the possibility of finding a relationship with the actual performance. In addition, during data collection, we observed that young children found it hard to rate their perceived level of comfort of the different grips. In light of these findings we suggest that future research should score the perceived level of comfort of each grip posture multiple times, such that the reliability of this measure can be established and eventually be improved.

The present study has limitations that should be noted. First, the small sample size inherently limits the generalizability of the results. Replication of the study in a larger group of children is warranted in order to improve reliability of the present findings. Second, the design of the study does not allow to exclude a simple learning or time effect. The inclusion of a control group, that does not receive any instructions between the two tasks, could overcome this. Furthermore, a retention test should be included to verify if children are (still) able to plan according to ESC after a longer period of time. Third, children received the training if they ended less than 100% of the trials in ESC on at least one of the tasks during the pre-test. Four children, that were included in the study, had a maximum score on one of the tasks during pre-test. Two of these children received the explicit goal instructions using that task, following the random balanced allocation of the specific training- and transfer-task. This made improvement in scores impossible, for these two children, and may have resulted in confusion, indicated by their decrease in score after training (see Fig. 2, graph at the top right). Future research should exclude children that immediately ended all trials in ESC on one or both tasks. Fourth, although the magic-wand-task was designed to match the task demands of the sword-task, the exact proportions of ESC on the two task sometimes differed across individual children and seemed to be somewhat higher for the sword-task compared with the magic-wand-task (see Supplementary material). Yet, given the counterbalanced design of the study and the moderate to high correlations between the pre-test measures of both tasks, we feel confident that this did not impact our findings. In this study we deliberately used two motor planning tasks with similar task demands to be able to study transfer effects, but for additional future research it would be also interesting to use motor planning tasks with various task demands to examine its effects on ESC planning after explicit goal instructions.

Finally, the results of the study may have value for clinical practice. The, at first glance, inefficient motor planning strategies that children often use could actually be adaptive and in accordance with task constraints that are different from maximizing ESC. In some cases, this prioritization of other task aspects may get in the way of efficient task performance. Our findings indicate that children could then benefit from explicit instructions regarding the goal of the movement. Furthermore, the results on the pre-test measure indicate that the individual differences within the group of children are high. While there was a group of children that ended none of the trials in a comfortable end-posture, there was also a group of children that immediately ended all trials in ESC. In addition, some children were able to adjust their plan quickly and used their new plan consistently, while others had much more difficulty with formulating and executing plans. For example, there was one child in the control group who did not end any of the critical trials in ESC also after the instructions. Given these inter-individual differences, the sword- and magic-wand-task and short training session could potentially be used as a screening measure to evaluate the motor planning behaviour of children and how well they can adjust their behaviour based on instructions.

In conclusion, our study is the first to show that both, children with pDCD and TD children, seem to be able to increase the use of grips resulting in ESC after explicit instructions that focused on the goal of the task. The majority of the children were able to adjust their strategy and to formulate and execute a plan to end their movements in a comfortable end-posture. Perceived comfort of handgrips was not different between groups. In both groups however, it was notable that the "uncomfortable" end-posture was not necessarily perceived as particularly uncomfortable, while the start-posture that was necessary to end in ESC was in fact. This may explain why children may prioritize other task aspects. Still, in the present study we found no direct relation with the task performance.

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CRediT authorship contribution statement

Daphne C. Koopmans: Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Project administration. **Hilde Krajenbrink:** Conceptualization, Methodology, Validation, Formal analysis, Resources, Data curation, Visualization, Writing – original draft, Writing – review & editing, Visualization. **Jessica Lust:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision. **Bert Steenbergen:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision.

Declaration of Competing Interest

All authors declare no conflict of interest.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.humov.2023.103066.

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