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MOTOR DISORDERS (P H WILSON, SECTION EDITOR)

Moving With Confidence: How Does Anxiety Impede Performance in Individuals With Developmental Coordination Disorder (DCD)?

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Abstract

Purpose of Review It is well-established that anxiety levels are higher among people with developmental coordination disorder (DCD) compared to their peers. However, it is unclear whether this anxiety influences movement and behaviour. The purpose of this paper is to review studies demonstrating the influence of anxiety on movement and/or behaviour in non-DCD and DCD populations.

Recent Findings When considering non-DCD literature, many studies have illustrated the influence of anxiety on movement. Only two papers were found which explicitly aimed to consider the influence of anxiety on movement in a DCD population. These findings are described and explored against a backdrop of the wider research field.

Summary This paper has highlighted the potential role of anxiety in constraining movement patterns in DCD. While a great deal more evidence is needed before definitive conclusions, there is emerging evidence that motor behaviour may be related to task-specific anxiety in children with DCD.

Keywords Developmental coordination disorder · Constraints-based approach · Anxiety · Task-specific anxiety · Movement

Introduction

The core characteristics of developmental coordination disorder include difficulties with fine and/or gross motor skills relative to their typically developing peers, which has a negative impact on activities of daily living, scholastic achievement and vocational choices [1]. These difficulties persist in late childhood and also throughout adulthood [2]. Unsurprisingly research to date has typically focused on how that motor skill or motor deficit manifests and affects people with DCD. Examples of the secondary consequences associated with DCD include deficits in executive function [3], lower levels of cardio-vascular fitness [4] and an increase in internalising symptoms such as depression and anxiety [5]. In this paper, we will focus on anxiety, firstly we will outline the evidence which demonstrates this as a secondary consequence to the core characteristics of DCD and secondly, we will consider the impact this anxiety might have on movement itself.

Before reviewing the literature, however, it is important to consider how anxiety might be conceptualised. When considering whether anxiety is higher in one population compared to another, studies typically use questionnaire methods to measure generalised anxiety, trait-anxiety (a more stable personality feature) or state-anxiety (activated in response to events over the past few weeks). However, in the studies we describe in this paper some studies also look at anxiety in response to a specific situation such as walking down the stairs (we term this task-specific anxiety). Other studies simply manipulate anxiety by giving participants a task which is considered to induce anxiety and compare that to a situation which is considered low anxiety. Finally, some studies also include physiological measures of stress and anxiety such as heart rate and galvanic skin response [6].

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The Influence of DCD on Anxiety

As alluded to above, in recent years there has been a growing body of research which demonstrates a higher level of anxiety in people with DCD. In fact, a recent meta-analysis considered internalising symptoms (anxiety and depression) in children and adults with DCD [5]. The combination of 22 studies yielded a medium effect size ($g = .61$) with higher levels of internalising symptoms found in DCD or probable DCD groups compared with typically developing controls. This review included some studies which focused only on anxiety, for example both state and trait anxiety were found to be significantly higher in children with DCD (8–10 years and 12–14 years) compared to their peers [7]. Similarly, children with DCD at 11 years of age had higher levels of anxiety, according to parental and child self-report using the Screen for Child Anxiety Related Disorders (SCARED) child and parent versions [8], than their peers [9].

Anxiety has also been considered in adults with DCD. Although a group without DCD was not included, Kirby and colleagues found that approximately 76% of their adults with DCD fell outside the 'normal' range according to a standardised anxiety questionnaire (Hospital Anxiety and Depression Scale) [10]. Furthermore, adults with DCD have reported significantly more symptoms of both state and trait anxiety compared to their peers (using the state-trait anxiety inventory) [11]. More recently, Harris and colleagues demonstrated higher levels of both generalised anxiety and movement-specific anxiety (anxiety which is specifically focused on movement) in a group of adults with DCD in comparison to their non-DCD peers [12]. For example, as well as feeling more anxious generally the adults with DCD felt more anxious about moving past objects such as displays in shops without bumping into them or about avoiding an obstacle appearing in their path such as a dog running out in front of them. This breadth and consistency of research has resulted in the recognition of anxiety (and more broadly mental health difficulties) as a secondary consequence of DCD [2]. This is in line with broader literature that has identified associations between motor ability and anxiety in community samples of typically developing adolescents [13] and adults [14].

The Influence of Anxiety on Movement

The literature cited above focuses on the influence of poor motor skill or poor motor function on anxiety in children and adults with DCD. However, it is also important to consider the impact that anxiety itself might have on movement. The constraints-based approach to understanding motor control can be helpful in describing and understanding motor control in DCD [2, 15, 16]. It posits that any emerging movement is constrained by the individual, the task and the environment [17]. Individual constraints originate from and are based within an individual organism, for example an individual's physical size constrains the movements which are possible as do other factors such as anxiety (see below for evidence of this). Task constraints are elements of a task that potentially act as a constraint upon an organism, for example emerging movements are constrained differently when walking on a soft surface as compared to a solid surface. Environmental constraints are aspects of the shared and surrounding environment that potentially constrain an organism, for example the weather or ambient lighting. These constraints interact and influence each other and can vary both between individuals (and indeed organisms) and also within individuals resulting in different emerging movements from one moment to the next. So taking the example above we would expect an individual's leg length to influence step length but also other factors such as anxiety would play a role here with an individual with high anxiety potentially taking shorter step lengths compared to an individual with low anxiety. Furthermore, when walking on a softer surface we would expect to see a shortening of step length compared to a firmer surface. Finally, lighting conditions would also influence step length, with shorter steps seen in the dark. If we consider all of these constraints together, we might see that walking in the dark, combined with a softer surface, combined with a short leg length, combined with a high anxiety (which could be state-anxiety or task-specific anxiety) would result in the shortest step length. This example is of course simplified as it includes only two potential individual constraints but it does conceptualise how these three types of constraint interact and influence movement.

If we consider the nature of DCD within this framework, the characteristic motor behaviours that we observe can be conceptualised as emerging as a result of a constraint—or set of constraints. Therefore, the movements we see in this population are emergent functional adaptations (or compensations if one wishes) to those individual constraints and the interaction between other individual constraints alongside task and environment constraints. For example, a series of studies considered emerging movements when individuals with and without DCD were asked to walk through apertures or gaps of varying sizes (some of which would force a shoulder rotation in order to fit and some of which would not). Broadly it was observed that children with DCD [18], adults with DCD [19] and typically developing young children [20] leave a greater safety margin between their shoulders and the apertures compared to their peers. Furthermore, a relationship was found between the individuals' movement variability (i.e. how consistently they control their medio-lateral movement) and the degree of safety margin; this relationship indicated that greater movement variability was linked to a greater safety margin [18–20]. Here we see movement variability constraining the emerging movement (the degree of turn or safety margin). Movement variability constrains both populations but the fact that this constraint differs between individuals with DCD and their peers might go some way to explaining why the emerging movement/behaviour is then also different. This is an example of what we would consider a compensation rather than a deficit; in this context, the emerging movement in the individuals with DCD is different but that does not mean it is less functional. The compensation, in this example, minimises the chances of a collision with the doorway by matching how accurately/consistently one can move with the amount of space they allow themselves. There may, however, be situations where the interplay between individual constraints and task constraints results in a less functional emerging movement. An example of this might be not lifting one's foot as high when walking to allow for a more time spent in double support. This reduces the balance demands, yet also increases the chance of tripping.

We now turn our attention to anxiety and consider this as an individual constraint. Before we review the literature, it is worth reiterating that anxiety can be influenced by a task requiring movement and anxiety can also influence movement its self. Where we are talking about anxiety as a constraint to movement the inference is that anxiety, whether caused by the movement task at hand, by a previous movement task or indeed by other life events, then goes on to influence or constrain subsequent movement. In a non-DCD population, there is clear evidence that anxiety can indeed be considered a constraint to movement (or indeed in some studies the perception of the movement). For example, anxiety was induced in a group of participants and then judgement of horizontal reaching distance, maximum grasp size and hand possibility was measured [21]. The anxiety induced participants consistently under-estimated their action capabilities as compared to those who had not had anxiety induced. Similarly, when anxiety was induced by asking participants to either climb to a high point on a climbing wall (high anxiety) or to a low point on a climbing wall (low anxiety), it was found that both perceived and actual maximum reaching height were reduced in the higher anxiety condition as compared to the lower [22]. Anxiety has also been shown to change movement, for example when running on an elevated treadmill (high anxiety) stride length was shorter and contact time was longer compared to running on a ground level treadmill (low anxiety) [23]. Self-report was used to check whether task manipulation changed anxiety levels, an 'anxiety thermometer' was used for this purpose, asking participants to rate their levels of anxiety immediately after the running task from 0 (not at all anxious) to 10 (very anxious). Self-reported anxiety levels were significantly higher in the elevated compared to the ground level condition.

The studies above have induced anxiety by placing participants in specific situations, but far less research has explicitly considered how one's natural level of anxiety constrains movement. One study, which did just that, looked at the point at which adults choose to step as compared to jump over a 'puddle' [24]. Data demonstrated that although an individual's perception of their action (i.e. what they say they will do) was related to their state-anxiety (measured via a questionnaire), their actual action (i.e. what they did) was not. For example, when verbally judging whether they would step over or jump over a puddle, those participants with higher reported anxiety said they would switch to a jump action relatively earlier than those with lower reported anxiety, while this difference was not seen when participants were asked to actually approach and pass over the puddle. This finding demonstrates a clear influence of anxiety on what we report we would do compared to what we actually do. However, in another study, participants diagnosed with clinical anxiety were characterised by slower walking speed, shorter step length and fewer steps per minute as compared to those with low anxiety [25]. This study demonstrates clear links between anxiety and differences in motor behaviour.

Physiological responses that accompany anxiety's influence on the motor system have also been explored, with high concordance shown between physiological and behavioural anxiety response components [26]. For example, in a study investigating balance in young (22–31 years) and older (60–83 years) adults, higher blood pressure and state anxiety (measured via a questionnaire) correlated with postural control changes (body stiffening strategies) in both age-groups when standing on a heightened surface [6].

The ageing population provides further insights into the influence of anxiety on movement and movement-related behaviours. A case study demonstrated that following a fall, state-anxiety increased by 23% in an 87-year-old female and that this went hand-in-hand with a change in gaze pattern during a stepping task which correlated with stepping error [27]. Although this is only a single case, it is a clear demonstration of change over time and how a change in anxiety seemingly goes hand-in-hand with a change in movement. This finding is not unique within the ageing literature and studies with much larger sample sizes (albeit not longitudinal) have demonstrated similar findings. For example, a walking study with 17 older adults included a measure of task-specific anxiety (self-reported on a 0–12 scale). Participants were required to walk along a 10-m walkway and step into a target; complexity was manipulated by introducing one or more additional obstacles. Higher anxiety was associated with an earlier shift of gaze away from the target and a greater number of missed steps (not accurately stepping into the target) [28]. Furthermore, when considering motor control rather than gaze a study using 100 older adults found that a group with high task-specific anxiety of falling demonstrated a higher stride length, a higher stride time variability and lower gait velocity compared to those with a low task-specific anxiety of falling [29]. Furthermore, stroke patients with high generalised anxiety showed distinctly different reach-and-grasp movements compared to those with low generalised anxiety (longer normalised movement time, lower and earlier peak velocity and delayed hand opening) [30]. This collection of studies, with many more not reported here, demonstrate a clear relationship between anxiety levels and characteristic of gaze behaviour and movement behaviour in older adults. Specifically, we see that a heightened level of task-specific anxiety negatively influences aspects of movement while walking and reaching. In fact, some of the compensations to heightened anxiety, such as those described above, are thought to result in a greater likelihood of a fall [28].

In light of the body of research described so far, it is striking that only two studies by the same research group have explicitly considered the potential effect of heightened anxiety on movement and movement-related behaviours in DCD. The first examined stepping behaviour while traversing obstacles in children with and without DCD [31••]. Participants were required to step into a target box while walking along a walkway. Task difficulty was increased by having no, one or two additional obstacles to step over. Of particular interest to the current paper, the authors also measured anxiety both at baseline and with reference to the task at each difficulty level. At baseline, the children were asked how anxious they felt about being in the laboratory and wearing the equipment for the study. Anxiety was measured using a child-appropriate 'fear thermometer' involving a 10-point 'smiley-face' Likert scale ranging from 1 (low anxiety) to 10 (high anxiety). They were then asked directly before each block of 5 trials comprising each difficulty level how anxious they felt about completing the upcoming trials (referred to by us as task-specific anxiety). Movement-related differences were observed between the groups, with the children with DCD showing less accurate anterior–posterior foot placement and an increase in step length variability. However, no group differences were observed in task-specific anxiety. Indeed, anxiety was highest at baseline across both groups, suggesting that any heightened anxiety response related more to fear of performing in front of new people in an unfamiliar environment than to a fear of falling during the walking tasks. Due to this lack of group difference, the authors did not consider whether anxiety was related to movement either within the DCD group or within the cohort as a whole. The lack group difference here could be due to the methods used to measure anxiety. A single question on a 10-point scale may not have allowed enough nuance to pick up on group differences and also some questions remain over a child's ability to reflect on their emotional state with any degree of validity [32] and physiological measures of anxiety may have elucidated this. This means that we cannot determine whether anxiety related specifically to the task was constraining the emerging action—this relationship could have been present across the groups (with children with higher anxiety in both the TD and DCD group walking more slowly for example) even though no group difference was observed in overall anxiety level.

Given the lack of difference in task-specific anxiety, Parr and colleagues go on to use a more ecologically valid task where the risk of falling is naturally greater such as when negotiating stairs. In this second study, children both with and without DCD were asked to either ascend or descend a seven-step staircase built in line with UK regulations for step size in domestic settings [33••]. Differences were once again seen between the group with DCD and their peers and this was true for both stair ascent and descent. In general, both tasks demonstrated greater handrail use, longer movement time, longer step durations and greater variability in toe/heel clearance in the children with DCD compared to the controls. However, once again for stair ascent no differences were seen in task-specific anxiety (this was measured prior to the task and in the same was as for their previous paper) and so the relationships between behaviour and anxiety were not explored. However, for stair descent clear group differences were observed in task-specific anxiety (higher in the children with DCD compared to their peers). Therefore, the authors explored the relationships between some of the movement-related differences and state-anxiety. Significant positive relationships were found between time taken to descend and task-specific anxiety, between variability in time taken to descend and task-specific anxiety and the number of steps ahead that gaze fell and task-specific anxiety. As such, considering behaviour across those with and without DCD, higher task-specific anxiety was associated with longer movement times and more variability in movement time as well as a strategy which involved sampling further ahead of one's current position. This is the first study, as far as we are aware, to explicitly consider how task-specific anxiety influences the emerging movement in DCD. In the ageing literature, direct relationships have been identified between those adults who are more anxious about falling and adaptations to gait which might actually make falling more likely [28]. The findings in DCD do not quite extend this far; however, from the Parr et al. study [33••] we see that anxiety while descending the stairs is linked to adaptations (i.e. looking away) which may make tripping/falling more likely. Furthermore, self-reports from adults with DCD suggest that increased anxiety may have a negative impact on perceived safety while walking [34•]. Therefore, we could infer that some of the group differences we see between individuals with DCD and their peers may be compensations (or indeed mal-adaptions) for heightened anxiety which, the paradoxically, may make the movement more dangerous.

An important consideration here is that of cause and effect, is it the potentially mal-adaptive movement which induces anxiety or is it the anxiety (or anticipation of moving) which results in the mal-adaptive movement? To some extent this can be inferred from the data we have available, the two Parr et al. studies both measured anxiety before the motor task which might suggest that the anxiety influences the movement, however, past experiences of moving may feed into that anxiety rating. The constraints-based approach, as stated above, posits that a movement emerges from the constraints at a given time point and that these constraints can vary within and between individuals. In this paper, we have demonstrated that anxiety, albeit task-specific (anxiety about the specific movement) or more general state/trait anxiety can act as a constraint to an emerging movement such as walking down the stairs. But we must also bear in mind that anxiety level may be higher (or indeed lower) the next time that individual walks down the stairs; this altered level of anxiety might once again be due to a change in task-related anxiety (because of what happened last time) or be due to unconnected life events or indeed differing environmental or task constraints. Within the context of DCD, this would suggest that task-specific anxiety and potentially generalised state/trait anxiety may influence the emerging movement but we must also bear in mind that individual's previous experiences with a given task might influence that anxiety level. Whether in fact state/trait anxiety does influence movement in DCD remains to be seen.

If we consider the potential impact of anxiety on the movement of individuals with DCD, we might discover that some of the group by task interactions we see are, in part, driven by anxiety. In other words, anxiety may only act as a constraint under specific task constraints. For example, this could explain the lack of group differences seen in gait on a firm surface contrasted with the emergence of group differences when walking on a compliant surface [35]. There are many other examples of this, such as when we see small group differences in road crossing decisions for single lane crossing decisions, but far greater group differences for dual lane crossing decisions [36]. In both examples, we can see the interplay between the individual constraints (which would include both the motor control ability defining DCD and potentially anxiety) interacting with the task constraints (type of surface walked on or size of road to be crossed).

Support of the idea that anxiety might influence behaviour in DCD comes from a recent study that asked both adults with DCD and parents of children with DCD about their road-crossing experiences [37•]. Both groups cited caution and lack of confidence as a way in which they differed from their peers when it came to crossing the road. This study did not explicitly link movement or behaviour change to anxiety in these situations, but this research does suggest a potential lack of confidence and associated elevated caution which may be linked to task-specific anxiety. Furthermore, it is also interesting to consider whether higher trait anxiety combined with and potentially influenced by motor ability may impede an individual with DCD's engagement with—and therefore the opportunity to practise and become more proficient in—various movement types. This was highlighted by Warlop and colleagues where differences in gaze behaviour shown by young adults with DCD during a hazard perception test for cyclists were noted to have potentially been due to a lack of cycling experience [38•]. The authors linked this to evidence that young cyclists with little experience had delayed first fixations and slower reaction times to hazards than older cyclists with more experience [39, 40]. A lack of experience cycling in traffic—which could be influenced by higher trait anxiety levels linked to motor ability—may therefore play a role in this 'immature' gaze behaviour of individuals with DCD. It is worth noting that this paper did not explicitly measure anxiety.

An important side note here is the issue of anxiety measurement. There is a real mix in the studies reported here as to how anxiety is measured and what is focused on when measuring it. The studies focusing on DCD [31••, 33••] asked participants about their anxiety regarding specific lab-based environments and upcoming tasks using child-appropriate self-report scales to classify anxiety level. Although these scales are simple, the authors point out that they have been validated against larger, more complex state-anxiety inventories [41]. However, both studies also note the age of the participants as a limitation since maturity may affect the validity of simple self-reported anxiety. Future research would therefore be enhanced by capturing physiological measures of anxiety to complement self-report. What is more, the measure used in these two studies is far from a measure of general anxiety and it is general anxiety which has predominantly been highlighted as higher in groups with DCD (for example see [5]), although some evidence exists showing that this also extends to movement-specific anxiety [12]. However, what remains unclear is whether when performing a task which does not inherently invoke heightened anxiety in a group with DCD (i.e. like that seen in Parr et al. [33••]) whether state or trait anxiety would still influence or constraint the emerging movement.

Concluding Remarks

If one is feeling anxious about a specific activity or movement, be it riding a bicycle safely, crossing the road, walking down the stairs or carrying something precariously balanced then that anxiety can influence the way we move, though it may also be useful to consider how the way we move might influence how anxious we feel. This influence seems to be particularly marked in some populations and there is now emerging evidence demonstrating that motor control is related to task-specific anxiety in children with DCD, though the nature and directionality of the relationship needs further exploration. Indeed, the sparseness of this initial evidence highlights a specific area of research in DCD that needs building on. What is more, while the relationship between motor control and anxiety in individuals with DCD may impede certain aspects of performance—such as speed in completing a given movement—it may simultaneously facilitate compensation in ways that ensure the safe and effective completion of that movement.

Declarations

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent All reported studies/experiments with human or animal subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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