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The role of anxiety and self-efficacy in movement

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ABSTRACT

Previous research suggests that affective factors may influence perception of potential movement differently compared to perception during movement itself. To build on this the current study investigated the roles of general and movement-specific anxiety, self-efficacy, general resilience and motor control in how 41 adults with typical motor skills thought they would behave (perceptual judgement) and how they actually behaved (executed action). Participants completed several standardised scales and two movement-specific scales, a perceptual judgement task and an executed action task. In the perceptual judgement task participants judged whether they would need to turn their shoulders to walk through different sized apertures between 0.9 and 1.9 their shoulder width-to-aperture ratio. This involved a static (standing still) and a dynamic (walking towards) condition. The executed action task involved actually walking through the different sized gaps between the doors. Findings were discussed within an ecological framework drawing strongly on Newell's constraints-based approach (1986). Results indicated a relationship between higher movement-specific anxiety and bigger safety margins. This highlights the importance of measure specificity in being able to detect nuanced relationships between affective factors and the perception-action cycle. Notable differences were also shown in the point of behaviour change (critical ratio) between perceptual judgement and executed action, illustrating the importance of studying perception and action together since they can be subject to different constraints. The findings contribute novel insights into the roles of these factors in how adults with typical motor skills perceive and realise their intentions and abilities to act in the world.

1. Introduction

The ecological account of psychology is concerned with the unity of perception and action. Within this broader conceptual framework Gibson (1977) developed the term 'affordance' to describe how the nature of objects in the environment interacts with an individual's characteristics to provide possibilities for action. Key to this is the notion that an individual organism embedded in their environment knows and interprets their environment *because* they perceive affordances, i.e., the possibilities for action available specifically to them in that specific environment. Where an environment is the same, different individual characteristics make for different affordances. For example, a south-facing windowsill affords a person a surface to place a vase of sunflowers, but it affords their cat the perfect spot to sunbathe (as well as a conveniently placed vase for a refreshing drink). A coffee table affords an adult somewhere to put their cup, but for a small child it affords a place to climb up and reach that shelf of things that surely must be toys. It is important to note that affordances exist regardless of whether they are actually perceived since they are located in both the material properties of environment and perceiver, and although they are not always actively perceived they can be focused on and engaged with

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selectively (Warren & Whang, 1987). The affordance relation therefore guides behaviour through an individual's perception of the 'fit' between their body and the environment in the context of potential and executed action (Gibson, 1979).

In order to better understand affordances, Warren and Whang (1987) undertook a study focused on visually guided action while walking through apertures. In this study participants with a range of narrow and broad shoulders were filmed walking through apertures of different widths. Using this footage, the 'critical point', i.e., the point at which participants changed from frontal walking to turning their shoulders to pass through, was established. These were compared with the participants' perceptual judgements of whether they thought they could walk straight through the apertures without turning, in both a static (i.e., standing still) condition and a dynamic (i.e., moving towards the aperture) condition. The authors identified that the critical point fell at the shoulder-to-aperture-width ratio of 1.3, irrespective of body size. They also found that standing still and looking towards an aperture led to lower perceptual critical ratio judgements in both the static and dynamic viewing conditions, but once again this was irrespective of body size. In other words, the relative point at which individuals with *different* body sizes started to turn to fit through the apertures stayed the *same* in terms of the shoulder-to-aperture-width ratio. From these findings, Warren and Whang (1987) were able to conclude that affordance perception and movement behaviour are influenced by body dimensions.

Wilmut and Barnett (2011) extended the work of Warren and Whang (1987) and investigated how typically developing children aged 8–10 years old make action judgements and adapt their movement while navigating through apertures. Results revealed that children show a critical ratio of 1.61, suggesting that the process of making an action judgement is scaled differently to that of adults. Results also showed that both shoulder angle variability and lateral trunk variability could be used to predict shoulder angle at the door for larger apertures. This indicates that children do spatially and temporally adapt their movements according to aperture size like adults do, and furthermore supports the notion that children are sensitive to the constraints and dynamics of their own developing perception-action system. In other words, they account for the consistency of their own movement behaviour and are able to successfully scale their actions appropriately. This also links back to the findings from an earlier study undertaken by Savelsbergh, Douwes Dekker, Vermeer, and Hopkins (1998) suggesting that children with and without cerebral palsy could more successfully account for their own visual-spatial abilities in terms of body-scaling for aperture size when action was being used in conjunction with, and indeed in the service of, perception.

The constraints-based approach, which stemmed from Gibson's (1979) ecological approach, views the environment, the individual and the task as potential constraints on motor action within a perception-action context (Newell, 1986). With this in mind, for Newell (1986) the multitude of individual-, task-, and environment-based constraints at play in any given moment are constantly interacting and influencing one another. Following this reasoning, the nature and effect of any of these constraints can vary both between and within individual organisms, giving rise to the emergence of different perception-action cycles and therefore movements from one moment to another. We can consider the factors described above, body size and movement consistency as *individual* constraints to movement. Within the context of an aperture-crossing task, additional individual-based and physical-related constraints have also been explored such as whether the mover is sat in a wheelchair or walking (Higuchi, Cinelli, Greig, & Patla, 2006), and whether the mover is an older adult as compared to a younger one (Hackney & Cinelli, 2011, 2013a, 2013b).

Another individual-based constraint on the perception and execution of movement is affect. One element focused on in various studies of perceptual judgements of affordances is anxiety. Bootsma, Bakker, van Snippenberg, and Tdlohreg (1992) first studied anxiety's effects on perceptions of the 'reachability' of approaching objects. Their findings showed that higher anxiety affected the accuracy with which the salient perceptual information was picked up. However, interestingly, anxiety did not affect the critical ratio itself. The authors conclude from this that heightened anxiety can affect the perceiver's processing of relevant information without affecting the affordance itself. In a later study, Graydon, Linkenauger, Teachman, and Proffitt (2012) considered the influence specifically of induced state anxiety on the perceptual judgements of reaching and grasping ability which they then directly compared with actual action capabilities in these tasks. State anxiety fluctuates and exists in a given *moment 'characterised by subjective feelings of tension, apprehension, nervousness and worry, and by activation…of the autonomic nervous system'* (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983, p. 4). In this study the authors used a series of tasks with which they measured perceived and actual reaching ability, grasping ability and the ability to move the hand through apertures. Their results showed that participants in the more anxious group underestimated their real action capabilities consistently in all of the tasks compared to participants in a control group. In other words, higher anxiety led to more cautious assessments of what participants thought they could do. Graydon et al. (2012) concluded that state anxiety influences how affordances are perceived in near space and that higher anxiety leads to withdrawal behaviours.

A later study undertaken by Pijpers, Oudejans, Bakker, and Beek (2006) showed that higher state anxiety, induced by placing participants at a height where they would have an increased fear of falling, decreased both their perceived and actual maximum reaching height while completing a wall-climbing task. The authors conclude that their findings call attention to the role emotional state plays in perceiving and realising affordances. They see their results as contributing to an evidence base showing that changes in emotional state coincide with changes to affordance and action perception. Related to Pijpers et al.'s (2006) approach and in a return to the aperture-crossing paradigm, Hackney, Cinelli, Denomme, and Frank (2015) later investigated the relationship between postural threat, action capabilities and identifying possibilities for action (in the context of the passability of apertures). They did so by challenging participants' ability to maintain their balance by asking them to walk along a narrow and elevated pathway to pass through apertures ranging from 1.1 to 1.5 times their shoulder width. Compared to a 'normal' walking condition on a ground level path that was not narrowed in any way, the elevated walking condition gave rise to decreased walking speed, increased trunk sway and a larger average critical ratio. Anxiety provoked by a perceived and actual threat to physical balance therefore appears to influence movement behaviour, in this case illustrated by aperture-crossing behaviour.

Studies, such as those discussed above, which have investigated state anxiety's effect on perceptions of affordances and action perception, have tended to use induced high and low anxiety conditions. In a more recent previous study however, (Harris & Wilmut,

2020) aimed to address a lack of research into everyday state anxiety's impact on the perception of everyday actions in typically developing adults. Everyday state anxiety can be defined as an individual's baseline level of state anxiety in a given moment without the presence of any task- or environmental factors designed to induce any heightened anxiety. State anxiety was measured using the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). Using a similar methodological approach as previous aperture studies (e.g., Wilmut, Du, & Barnett, 2016), participants were asked to make perceptual judgements and perform the associated action in relation to crossing over ground-based apertures of different sizes which represented puddles. The critical ratio in this case was the aperture size, relative to participants' leg length in cm, at which crossing behaviour (judgement or actual) switched from a step to a spring. Interestingly it was found that perceptual judgement critical ratio could be predicted with state anxiety, whereas action critical ratio was not. These results suggest that everyday state anxiety may constrain perceptual judgement of action capabilities, but this may not be reflected in emergent movement behaviour. Despite methodological differences, this does recall Bootsma et al.'s (1992) earlier finding that anxiety state may affect perceptual information pickup without affecting an affordance per se. Once again, these findings illustrate the value of measuring movement behaviour instead of inferring it from perceptual judgements, even when these are embedded in a context of action. Looking through the lens of the constraints-based approach, this finding suggests that affective factors - including anxiety - may constrain perception of potential action (where no actual movement is involved) differently, compared to perception during the execution of the same action, where movement is involved.

To build on previous research, the current study aimed to investigate the roles of anxiety and movement variability in how adults with typical movement think they will behave (their perceptual judgement) and how they actually behave (their executed action). In addition, to broaden out the consideration of non-physical contributions to movement we also explored the roles of resilience and self-efficacy. Resilience is defined as the ability to adapt positively and "bounce back" in the face of adverse experiences (Southwick, Bonanno, Masten, Panter-Brick, & Yehuda, 2014). A related yet distinct concept, self-efficacy -which can be general or domain-specific – is an individual's judgement in relation to themselves of how well they can enact courses of action needed to successfully navigate and deal with prospective situations (Bandura, 1982).

For perceptual judgements it was hypothesised that higher anxiety, lower self-efficacy, and lower resilience would correspond with more cautious perceptual judgements of action capabilities in both static and dynamic task contexts (i.e., a higher critical ratio). Additionally, it was hypothesised that more consistent movement control (i.e., lower movement variability) would correspond with less cautious perceptual judgements relating to lower critical ratios in both static and dynamic task contexts. The hypotheses regarding executed action were based on previous findings from studies involving similar aperture-crossing tasks. In spite of Harris and Wilmut's (2020) finding, due to the increase in sample size in the current study and the use of several nuanced measures of anxiety and the other affective factors, it was hypothesised that higher anxiety, lower self-efficacy and lower resilience would correspond with more cautious executed actions (i.e., higher critical ratio and relative safety margin). Relative safety margin is the amount of space an individual leaves between their body and the edges of a space they need to pass through by turning to a greater or lesser degree to avoid bumping into the sides. We can think of a safety margin as being the effect of what is *actually* possible versus what is *comfortably* possible (e.g., Mark et al., 1997; Wagman & Malek, 2009). It is notable that there is some debate regarding the factors that cause differences in safety margins across different types of movement behaviour. There are some researchers who interpret safety margins as a way of taking into consideration the dynamics of the body in motion. In the case of walking through apertures, these would for example be the way the body oscillates from side to side which effectively increases body width (e.g., Franchak, Celano, & Adolph, 2012; Wilmut & Barnett, 2011). With this in mind, different constraints – including more variable movement and how anxious or confident an individual may be feeling - could lead to increased safety margins, hence the hypothesis outlined here.

Linked to this, it was additionally hypothesised that more consistent movement control (i.e., lower movement variability) would correspond with less cautious executed actions, in the form of lower critical ratios and smaller relative safety margins. It was hypothesised that critical ratio may vary across the three task conditions: static perceptual judgement, dynamic perceptual judgement and executed action. In light of the increased perceptual information on offer as the perception-action cycle progresses through the three conditions, it was expected that critical ratio would be lowest in the static perceptual judgement condition, then higher in the dynamic perceptual judgement condition and then highest in the executed action condition.

Please note, this study was pre-registered on the Open Science Framework (Registration DOI: 10.17605/OSF.IO/YN9FM). The research undertaken in the current study was approved by the University Research Ethics Committee, Oxford Brookes University (UREC reference number: 201422).

2. Methods

2.1. Participants

41 adults with typically developing motor skills[1] (33 identified as women and 8 as men) aged 18–55 years (mean age 27.7 years) participated in this study. Participants were recruited via the Oxford Brookes Research Participation Portal and Psychology Participant Panel, social media advertising, as well as personal and professional contacts of the researcher. Participants self-reported no movement difficulties and also had to score below 56 on the total scale and below 17 on section A of the Adult Developmental Coordination Disorder/Dyspraxia Checklist (ADC; Kirby, Edwards, Sugden, & Rosenblum, 2010) to ensure their inclusion (i.e. below the cut-off

[1] Despite the typical motor skills, five reported having dyslexia, one reported a diagnosis of attention deficit hyperactivity disorder (ADHD), one suspected ADHD, one reported having ADHD and dyslexia and one reported having ADHD and autism spectrum disorder (ASD).

scores indicating movement difficulties during childhood and being ‘at risk for Developmental Coordination Disorder (DCD)’ in activities for daily living during adulthood). In line with this, two prospective participants who scored above the aforementioned cut-off point on the ADC had to be excluded from the final sample ($N = 41$).

2.2. Apparatus

A six infrared-camera VICON™ 3D motion capture system (Oxford Metrics Ltd., Oxford, UK) tracked movement in the executed action task. Reflective markers were placed on the left acromion process (LAP), the right acromion process (RAP) and the seventh cervical vertebra (C7). The cameras captured a 5.5 m × 3.5 m area where participants walked towards and through apertures between two wooden doors (2 m × 1 m) on moveable bases. A further three reflective markers were placed on the inner edges of these doors to facilitate identification during data processing. The VICON™ system tracked medio-lateral movement along the x-axis, anterior-posterior movement along the y-axis and vertical movement along the z-axis. The doors were wheeled back and forth along a laminated ruler line (cm) placed on the floor to form six shoulder-to-aperture (SA) ratios between 0.9 and 1.9, rising by increments of 0.2, for each participant. The ruler was laminated so that fine-tipped washable marker pen could be used to mark the different points (in cm) for each participant's specific SA ratios.

2.3. Measures

Participants completed a series of questionnaires. The first task was a paper-based State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) followed by a series of questionnaires presented on a laptop with the software Qualtrics XM™. The digital component included three standardised scales. These were the New General Self-Efficacy Scale (NGSE; Chen, Gully, & Eden, 2001), the Brief Resilience Scale (BRS; Smith et al., 2008), and the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983). It also included two ten-item scales developed by the researchers to measure movement-specific self-efficacy and movement-specific anxiety (Harris, Wilmut, & Rathbone, 2021). These were developed using guidance from Bandura (2006) on constructing self-efficacy scales for specific domains; in this case, moving around an everyday environment on foot. Using a visual sliding scale, participants rated their ability (for the self-efficacy scale) or the degree of anxiety they generally feel regarding their ability (for the anxiety scale) to carry out five kinds of everyday actions in quiet and busy environments. Example items are: (i) Estimating the space needed when walking between two objects (for example, between tables in a restaurant or two parked cars) and (ii) avoiding an obstacle that appears in your path (for example, a dog running out in front of you).

The Adult DCD/Dyspraxia Checklist (ADC; Kirby et al., 2010) was additionally included to further screen participants, along with an informal interview, for the necessary inclusion criteria to qualify as adults with typically developing motor skills. Informal questions were also asked to establish the absence of any motor skill difficulties resulting from other conditions that could affect movement such as visual impairments or neurological conditions.

2.4. Procedure

Initially participants completed the STAI followed by questionnaires presented digitally, those in the digital component were presented in counterbalanced order.

Shoulder width (the distance between the right and left acromion process) was then measured in cm and used to calculate the six shoulder-to-aperture (SA) ratios between 0.9 and 1.9. Following this, participants completed two perceptual judgement tasks (one static and one dynamic) and an executed action task which were presented in a counterbalanced order. Details of the three types of task are given below and an illustration of the set-up can be found in Fig. 1.

Perceptual Judgement Task, static condition: participants stood 6.5 m facing away from the aperture created between the two moveable doors. On turning around, they were presented with an aperture at one of six SA ratios (0.9, 1.1, 1.3, 1.5, 1.7 or 1.9 times their shoulder width). They were asked to judge whether they thought they could walk through the presented aperture with or without turning their shoulders by stating either ‘turn’ or ‘no turn’. After each judgement, participants turned to face away from the aperture while the researcher changed the size of the aperture. This component of the experiment consisted of 18 trials which were presented in the same pseudo-randomised order to each participant, with each SA ratio appearing three times.

Perceptual judgement task, dynamic condition. This followed the same procedure as described above, the only difference being that participants turned to face the aperture and then walked forward 2.5 m onto a square blue mat (placed 4.5 m from the aperture) before making their judgement in the way described above.

Executed action task. This consisted of 30 trials presented in the same pseudo-randomised order to each participant, with each SA ratio appearing five times. Once again participants started 6.5 m from the aperture and began each trial facing away from the moveable doors. Upon the initiation of a trial, participants were asked to turn around and walk towards and through the aperture to a stop-point in front of the wall behind the doors. Movement was captured from the point at which participants were within 4 m of the aperture up to the point of passing the aperture's threshold. The researcher indicated that some of the apertures would require participants to turn their shoulders, while others would not and that the participant should simply walk through in a way that felt natural to them.

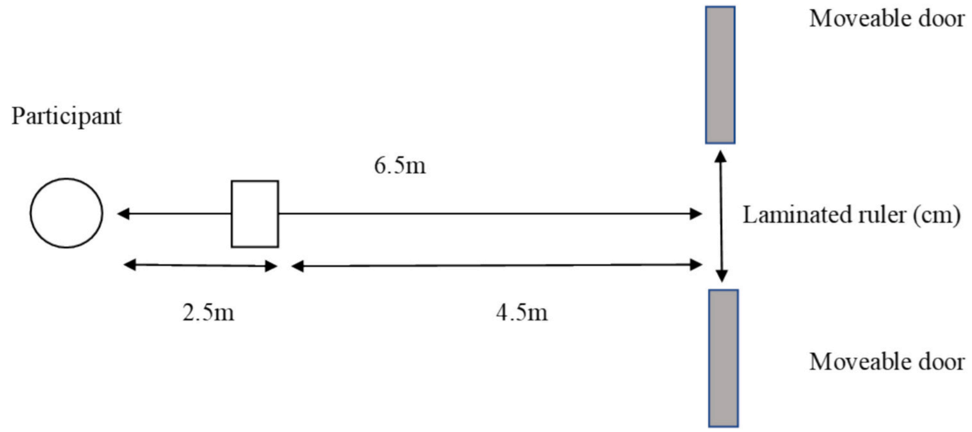

Fig. 1. Illustration of apparatus and set-up for all three tasks. Please note, the small rectangular shape is the blue mat described in the perceptual judgement task, dynamic condition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.5. Data processing

Sum scores from the NGSE, BRS, HADS, STAI and the ADC[2] were calculated according to the instructions for each scale. Mean values were calculated for each movement-specific component: movement-specific anxiety and movement-specific self-efficacy (in line with Harris et al., 2021).

With regards to the movement data any gaps were filled and then all data was filtered using an optimised low pass Woltring filter with a 12 Hz cut off point to screen any noise and smooth the data. Tailored MATLAB™ (MathWorks) routines were used to extract the movement variables of interest. Aperture and shoulder width were calculated with the *x* and *y* position of the door markers and the RAP and LAP markers. The movement data was split into two phases: the approach phase (first two seconds of movement captured) and the passing phase (point at which the C7 marker came level with the doors).

The following variables were extracted by the MATLAB programme during the approach phase. **1. Baseline sway (°),** of the first four steps from the point at which movement was captured by the VICON™ system (i.e. from 4 m away from the aperture) captured the maximum angles between RAP and the LAP with respect to the frontal plane were calculated in radians and then converted to degrees; **2. Approach speed ($\mathbf{ms^{-1}}$),** of the first two seconds of movement captured a derivative of displacement data was taken before applying a least-squares approximation method to determine a trend line of C7's movement with a speed-time profile for each trial (as in Higuchi et al., 2006; Wilmut & Barnett, 2011). All measures of movement speed were subsequently taken from the aforementioned trend line; **3. Lateral trunk movement (mm),** the average and standard deviation of the cumulative lateral movement of C7 across the approach phase giving both lateral trunk movement and lateral trunk movement variability.

During the passing phase the MATLAB programme extracted two variables: **1. Shoulder angle at the door,** the angle between the shoulders, with respect to the initial frontal plane, as C7 passed through the aperture, calculated the same way as the baseline sway variable. This variable was used to determine whether or not a turn had occurred. A turn was identified if the shoulder angle at the door was greater than one standard deviation above baseline sway (aligning with the approach taken by Wilmut & Barnett, 2011; Wilmut, Du, & Barnett, 2015; Wilmut et al., 2016); **2. Mean relative safety margin,** at the point at which C7 crossed the doors the medio-lateral distance between the shoulders was calculated and subtracted from the actual aperture size, giving a measure of the absolute gap between the shoulder and the door. This was then divided by shoulder width to provide the proportion of an individual's shoulder width that they chose to leave as a 'safety margin' between their body and the door edges. For example, a value of 0.5 indicates that the individual left the equivalent of 50 % of their own shoulder width between the edge of their shoulder(s) and the door edges. This could be 25 % on each side or a different distribution. As such, a higher value indicates a more cautious approach. The final variable calculated was the **critical ratio** which is defined as the SA ratio (as measured according to the calculations made by the VICON™ system using the *x* and *y* position of the door markers and the RAP and LAP markers) at which a participant's behaviour changes from *not turning* their shoulders to pass through an aperture, to *turning* their shoulders to pass through an aperture. The critical ratios were calculated for each participant and represent the aperture ratio at which the participant judged that they either 'would turn' or actually did turn on 50 % of the trials (as in Harris & Wilmut, 2020; Warren, 1984). The percentage of 'turn' responses for each SA ratio was calculated for each participant across each task. For the perceptual judgement task – in both the static and the dynamic conditions - the largest aperture width at which participants stated they would 'turn' for more than 50 % of the time (i.e. a 66 % or 100 % 'turn' response) and the smallest aperture width at which participants stated that they would 'turn' for less than 50 % of the time (i.e.

[2] The ADC scores were not used as part of subsequent statistical analyses but only to ensure that participants met the aforementioned inclusion criteria.

a 33 % or 0 % 'turn' response) were graphed. This created a straight line, the formula for this was derived and the aperture width at which 50 % turn responses would be expected was calculated. An example to illustrate this is shown in Fig. 2 below.

2.6. Statistical analysis

Data was analysed in the open-source computer software jamovi to conduct statistical analyses on the data (The jamovi project, 2021). In relation to comparing the critical ratios across all task conditions, Pearson correlations were performed to examine the relationships between these in the static perceptual judgement condition, the dynamic perceptual judgement condition and the executed action condition. Following this, a repeated measures Analysis of Variance (ANOVA) was performed to analyse the effect of condition (static vs dynamic vs executed action) applying the Greenhouse-Geisser correction where appropriate and using a Tukey correction for post-hoc testing. To determine factors which influenced critical ratio and aspects of movement, Pearson correlations were first examined between all relevant variables to take into account multicollinearity and subsequently decide which variables to use in regression analyses. Hierarchical multiple regression analyses were then performed to examine whether and to what extent the variables chosen for inclusion predicted critical ratio/aspects of motor control in the executed action condition. Theoretically-driven choices were made relating to the order and composition of the three models included in the hierarchical multiple regressions. General anxiety and movement-specific anxiety were added to the first model in light of previous findings suggesting that higher anxiety is linked to higher perceptual critical ratios during perceptual judgements of affordances in typical populations. Since the effect of self-efficacy in this regard remains unexplored and is an affective construct that may relate to anxiety, general self-efficacy and movement-specific self-efficacy were added to the second model. A third and final model involved the addition of movement variability, added last because in adults with typical motor skills this is likely to be comparatively lower than in populations with a greater degree of movement variability such as children.

3. Results

3.1. Critical ratios

The differences between the mean critical ratio values across these three conditions is shown in Table 1.

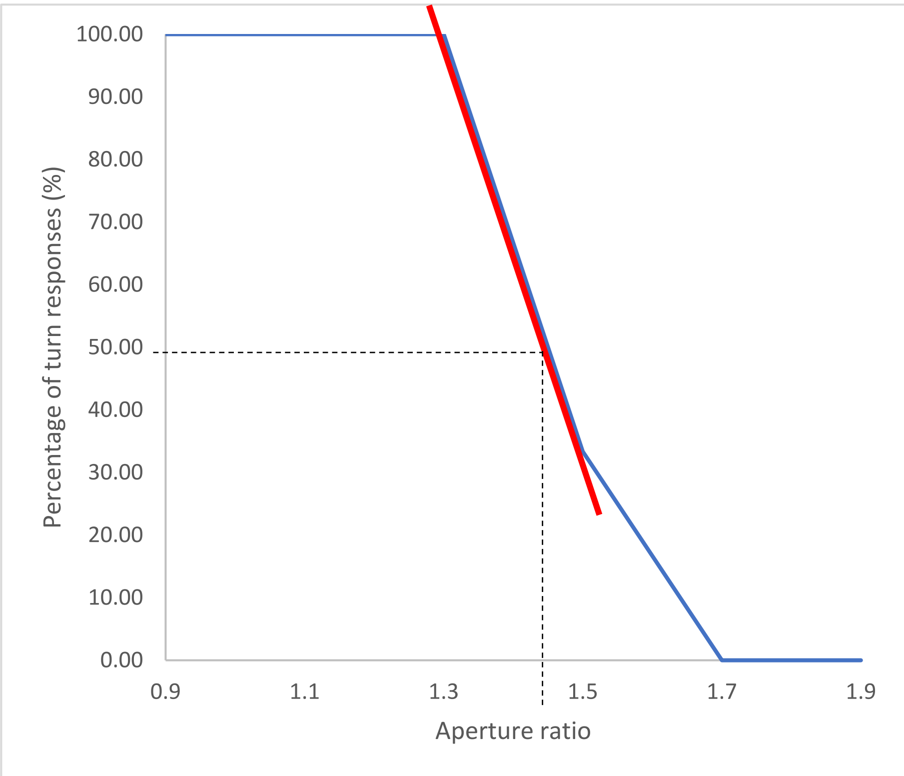

Fig. 2. Graph illustrating where the 50 % response rate fell for a participant in the dynamic perceptual judgement condition. The fitted line crossing the data is shown in red. Please note, the equation of the red line is: percentage of responses = −333.333 (shoulder aperture ratio) + 533.33. Therefore, if the percentage of responses in 50 %, the shoulder aperture ration in this example is 1.45. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Estimated marginal means of critical ratios across task conditions along with the kinematic measures of movement.

Condition	Mean	SE	95 % Confidence Interval	
			Lower	Upper
Static Perceptual Judgement	1.19	0.125	1.15	1.23
Dynamic Perceptual Judgement	1.21	0.145	1.17	1.26
Executed Action	1.26	0.118	1.22	1.30
Approach speed (ms^{-1})	1.24	0.146	1.20	1.29
Baseline Sway (^{o})	6.08	1.73	5.55	6.61
Mean relative safety margin	0.769	0.098	0.739	0.799

The critical ratios across all three task conditions correlated significantly with one another. There was a positive and highly significant correlation between critical ratios in the static perceptual condition and the dynamic perceptual condition, $r(39) = 0.767$, $p <$ .001, the static perceptual condition and the executed action condition $r(39) = 0.506$, $p < .001$ and the dynamic perceptual condition and the executed action condition, $r(39) = 0.333$, $p < .033$. A repeated measures Analysis of Variance (ANOVA) was performed to examine the effect of condition on critical ratio. The repeated measures ANOVA revealed a statistically significant effect of condition on critical ratio, $F(1.54) = 7.35$, $p = .003$, partial $\eta^2 = 0.14$ (Greenhouse-Geisser correction). Post-hoc pairwise comparisons indicated that there was no significant difference between the critical ratios in the static and dynamic perceptual judgement conditions nor between the critical ratio in the dynamic perceptual judgement condition and the critical ratio in the executed action condition. However, the critical ratio in the executed action condition was significantly higher than the critical ratio in the static perceptual judgement condition, $p$tukey = 0.001.

3.2. Influencers of critical ratio

Initial Pearson correlation analyses indicated highly significant multicollinearity between data from the BRS and the HADS, $r(39) = -0.627$, $p < .001$, and the NGSE, $r(39) = 0.605$, $p < .001$. Significant multicollinearity was also evident between the STAI-S, the STAI-T and the HADS, $r(39) = 0.423$, $p = .006$; $r(39) = 0.765$, $p < .001$. In light of this, to mitigate the possible effect of multicollinearity affecting subsequent regression analyses, it was decided to include only data from the following wellbeing variables: general anxiety (as measured by the HADS), general self-efficacy (as measured by the NGSE), movement-specific anxiety and movement-specific self-efficacy. Please note that data from the movement-specific anxiety scale also correlated significantly with data from the HADS and the NGSE ($r(39) = 0.451$, $p = .003$; $r(39) = -0.409$, $p = .008$), as did data from the movement-specific self-efficacy scale ($r(39) = -0.487$, $p = .001$; $r(39) = 0.418$, $p = .007$). However, it was decided to enter these into the regression analyses as separate variables since these correlations were moderate in strength and due to specific interest in these variables. Descriptive details of the data from the wellbeing variables chosen for inclusion in subsequent regression analyses are shown in Table 2.

It was notable that there were no significant correlations between any of the wellbeing variables, or indeed between movement variability in the executed action condition, and the critical ratios in either the static or dynamic perceptual judgement conditions. For this reason, the planned hierarchical multiple regressions are not reported. In addition, none of the wellbeing variables of interest correlated significantly with executed action critical ratio. Lateral trunk movement (representing movement variability) also did not correlate significantly with either critical ratio or mean relative safety margin. As such once again the planned hierarchical multiple regressions are not reported.

3.3. Influencers of movement control

While critical ratio measures the point at which behaviour changes, it does not necessarily describe how movement is controlled. Therefore, factors influencing measures of movement control were also considered. The measures of movement control under scrutiny were: mean approach speed, mean baseline sway and mean relative safety margin. For each of these variables an average across the SA ratios was taken. Details of these variables can be found in Table 1.

Movement variability did not correlate significantly with mean relative safety margin, baseline sway or approach speed. In addition, we saw no significant correlations between the measures of wellbeing and baseline sway or approach speed. However, there were significant correlations between mean relative safety margin and the following wellbeing variables: general self-efficacy, $r(39) =$

Table 2
Descriptive details of data from anxiety (HADS and MS anxiety) and self-efficacy variables (NGSE and MS self-efficacy) chosen for inclusion in regression analyses. MS = movement specific.

	HADS	NGSE	MS Anxiety	MS Self-efficacy
Mean	8.54	3.67	22.07	77.72
Standard deviation	3.78	0.48	19.55	14.42
Range	16	2.25	64.5	60.6
Minimum	1	2.50	0	39.4
Maximum	17	4.75	64.5	100

−0.362, $p = .02$, general anxiety, $r(39) = 0.379$, $p = .015$, movement-specific self-efficacy, $r(39) = -0.422$, $p = .006$, and movement-specific anxiety, $r(39) = 0.441$, $p = .004$. Therefore, a hierarchical multiple regression was performed in line with that described in the statistical analysis section. In terms of the overall results, in the first model, general anxiety and movement-specific anxiety were found to (significantly) explain 23.5 % of variance in mean relative safety margin, $R^2 = 0.235$, $F(2, 38) = 5.84$, $p = .006$. When added to the second model, general self-efficacy and movement-specific self-efficacy jointly did not contribute any significant increment in the percentage of variance explained, $\Delta R^2 = 0.023$, *Fchange* (2, 36) = 0.57, $p = .573$. When subsequently added to the third model, movement variability did not contribute any significant increment in the percentage of variance explained, $\Delta R^2 = 1.42 \times 10^{-4}$, *Fchange* (1, 35) = 0.007, $p = .935$. The results for each individual predictor within the regression model are shown in Table 3. In model one, movement-specific anxiety significantly predicted mean relative safety margin, $p = .04$. However, general anxiety was not significantly related to mean relative safety margin in model one. Neither general nor movement-specific anxiety were subsequently significantly related to mean relative safety margin in models two or three. In model two, neither general nor movement-specific self-efficacy made a significant unique contribution to the model. Finally, in model three movement variability did not make a significant unique contribution to the model.

4. Discussion

Considering first the results relating to perceptual judgements, the lack of significance in the correlation analyses, and in both of the regression analyses pertaining to static and dynamic perceptual judgement critical ratios is striking. These results did not align with what was hypothesised and are contrary to previous findings, especially those in relation to anxiety. As detailed previously higher anxiety has previously been shown to relate to more cautious perceptual judgements in a range of affordance judgement tasks, including the aperture-crossing paradigm used in the current study (for example, see Graydon et al., 2012; Hackney et al., 2015; Harris & Wilmut, 2020). The hypotheses regarding anxiety and the related factor of self-efficacy were therefore based on these previous findings. However, in the current study the results from the perceptual judgement tasks suggest that higher general and movement-specific anxiety and self-efficacy do not lead to more cautious perceptual judgements of the 'passability' of apertures in either a static or a dynamic context.

One reason for this contrast with previous findings may relate to the measurement of 'baseline' or everyday anxiety and self-efficacy in the current study. Most previous related studies were based around induced 'high' and 'low' anxiety conditions (e.g. Graydon et al., 2012; Hackney et al., 2015), which may relate to their detection of significant effects. An exception to this is the previous finding by Harris and Wilmut (2020) that higher everyday state anxiety led to more cautious perceptual judgements, but not to more cautious executed actions, among TD adults. This contrasting finding may relate to the use of different anxiety measures, or the difference could also be task related. Although Harris and Wilmut (2020) used a similar methodology and paradigm, the judgements were about ground-based apertures designed to represent puddles. In both the static and dynamic perceptual judgement conditions participants judged whether they would 'step' or 'spring' over the 'puddle' from a position directly in front of it. In the current study however, perceptual judgements in static and dynamic conditions were made at a distance of either 6.5 m or 4.5 m respectively from the apertures between the moveable doors. Furthermore, as was discussed by Harris and Wilmut (2020) as a limitation in their study, the perceptual judgement task always preceded the executed action task. Therefore, state anxiety level could have shifted between the perceptual and action tasks once familiarity with the lab and task set-up had been established. However, in the current study, to mitigate this the task order of the perceptual judgement conditions (static and dynamic) and executed action conditions were all counterbalanced. The findings between the two studies cannot therefore be wholly reliably compared. Moreover, given the differing natures of the task, there is potentially less of an inherent need for cautious judgements about the act of passing between two doors where the biggest risk is bumping gently into the side, as opposed to when judging the need to step or jump over a puddle which is not only a less common everyday action but also implies more risk in terms of possibly getting wet as well as the pressure a jumping action may place on the body. In light of these various aspects, the findings between the current study and Harris and Wilmut's (2020) study cannot therefore be wholly reliably compared. To address these issues, future research could repeat both Harris and Wilmut's (2020) 'puddle' task experiment with the task conditions counterbalanced, and/or could repeat the experiment undertaken in the current study using exactly the same measures and procedures as far as realistically possible but with a different everyday task that involved

Table 3
Hierarchical multiple regression results for the prediction of mean relative safety margin.

		B	*SE B*	*β*	*t*	*p*
Model 1	General anxiety	0.006	0.004	0.23	1.42	0.163
	Movement-specific anxiety	0.002	0.0008	0.34	2.13	0.040
Model 2	General anxiety	0.003	0.005	0.130	0.69	0.491
	Movement-specific anxiety	0.001	0.001	0.226	1.09	0.279
	General self-efficacy	−0.001	0.001	−0.143	−0.68	0.455
	Movement-specific self-efficacy	−0.028	0.037	−0.135	−0.76	0.500
Model 3	General anxiety	0.003	0.005	0.130	0.68	0.498
	Movement-specific anxiety	0.001	0.001	0.229	1.08	0.287
	General self-efficacy	−0.001	0.001	−0.142	−0.66	0.460
	Movement-specific self-efficacy	−0.028	0.038	−0.138	−0.75	0.511
	Movement variability	0.009	0.111	0.013	0.08	0.935

higher inherent risk so that results can be more directly compared and replicability more robustly tested.

Feeding into a broader view of the relationship between anxiety and perception, these differences in findings, alongside the potential roles of measurement and task type, imply that any effect of anxiety on perception is dependent on its nature and intensity. This is therefore a relationship or even set of relationships that are highly nuanced. As discussed by Harris, Purcell, and Wilmut (2022) and linking to the constraints-based approach (Newell, 1986), different types of anxiety – for example baseline trait anxiety versus anxiety related to a specific task – both constrain perception differently and are constrained by differing individual-, task- and/or environment-based factors.

Turning to consider the fact that no significant relationship was detected between movement variability and the perceptual judgement critical ratios, this is not necessarily surprising in adults with typical motor skills. Wilmut and Barnett's (2011) study highlighted the relationship between movement variability and executed actions, but their study did not involve perceptual judgements made outside of the associated executed actions and was also undertaken with children who had typically developing motor skills. Throughout childhood the consistency of movement is still developing and as such, by adulthood this may no longer be a significant factor in relation to the perceptual judgements of affordances in individuals with typical motor skills.

Moving on to consider the results relating to executed actions, analyses undertaken with data from the current study suggest that there are certain significant relationships between wellbeing and mean relative safety margin: so, between how anxious or confident in their ability somebody feels and how much space they leave between their own body width and the edges of the doors by turning to a greater or lesser degree to pass through the gaps between the doors without bumping into the sides.

Considering first the correlational evidence, it is notable that no significant relationships were detected between any wellbeing or movement variables and executed action critical ratio. However, significant correlations between several wellbeing variables and mean relative safety margin supported what was hypothesised in relation to anxiety and self-efficacy. Specifically, higher general and movement-specific anxiety, as well as lower general and movement-specific self-efficacy correlated with bigger relative safety margins, which could be interpreted as more cautious executed actions, i.e. movement behaviour. It is notable however that movement variability showed no significant correlations with either executed action critical ratio or mean relative safety margin, likely for similar reasons as discussed regarding the perceptual judgement tasks in that for adults with typical motor skills this may not be a significant factor in their execution of low-risk, everyday actions such as this.

Correlational evidence alone however offers limited insight, and the results from the regression analyses offer a more nuanced insight into both the detection and nature of such relationships. It is once again striking that no significant relationship was detected between anxiety, self-efficacy and/or movement variability and executed action critical ratio. This is likely for similar reasons as discussed above in relation to the static and dynamic perceptual judgement critical ratios. Although this does not align with what was hypothesised, in the case of executed action critical ratios it does align with Harris and Wilmut's (2020) previous finding that higher every day or baseline anxiety - as opposed to induced anxiety - does not impact action perception during the actual execution of movement behaviour in terms of critical ratio. However, it is interesting that when the movement behaviour - i.e. shoulder turning - was considered through the lens of mean relative safety margin the results showed that higher movement-specific anxiety was significantly related to bigger mean relative safety margin. In other words, those participants who were more anxious about their movement ability left a significantly bigger safety margin for themselves relative to their own shoulder width by turning to a greater degree to get through the gaps between the doors without bumping into the sides. Linking back to a point made in the introduction with regards to why a safety margin might differ, this particular finding may show anxiety acting as a constraint on the way in which people account for their body's dynamics in motion and in relation to changing task constraints (Franchak et al., 2012; Mark et al., 1997; Wagman & Malek, 2009). In this case specifically, it illustrates how anxiety may relate to accounting for body dynamics in the context of gaps becoming smaller between the doors. This could be interpreted as higher anxiety leading to a kind of 'over-compensation' in cautiousness, made manifest and detectable in this case through the variable of mean relative safety margin.

This finding therefore offers a novel insight into the nature of a potential relationship between anxiety and movement behaviour in typically developing adults. It furthermore suggests that to detect such a relationship, the nature of the anxiety measurement is important. Where scales which measure generalised anxiety, such as the STAI or HADS may not detect a relationship, a scale such as the novel one used in the current study designed to measure anxiety specifically in relation to the type of task under experimental study was able to detect this more nuanced relationship that may otherwise have gone undetected. It also indicates that, even if they are related, the nuanced differences between what can be detected by 'critical ratio' compared to another measure of movement behaviour - in the case of this task paradigm the mean relative safety margin - are essential to take into consideration. Although this finding in relation to relative safety margin is more difficult to compare with previous research that has focused on critical ratio as the key measure of changes in movement behaviour, it is interesting nonetheless. It illustrates the potential benefit in future of considering the measurement of movement behaviour from more than just the perspective of critical ratio. This can arguably offer less of a nuanced view as, by its nature, critical ratio offers more of a categorical view of behaviour change rather than the more graded or continuous view offered by a variable such as mean relative safety margin in this case.

This perspective shifts the focus towards *how* behaviour may be different in relation to factors such as anxiety rather than simply *whether* it is different. Indeed, except for Harris and Wilmut (2020) and Hackney et al. (2015), previous studies that have explored how anxiety might shape or change behaviour have illustrated this by measuring accuracy rather than the 'switch' from one behaviour (i.e., critical ratio) (e.g., Graydon et al., 2012; Pijpers et al., 2006; Stefanucci, Proffitt, Clore, & Parekh, 2008).

Turning finally to consider the results which compared the critical ratios across task conditions, critical ratios in the executed action condition were significantly higher than those in the static perceptual judgement condition. Although estimated marginal means illustrated that critical ratios in the dynamic perceptual judgement condition followed the trend that was hypothesised, it was not significantly higher than critical ratio in the static perceptual judgement condition. These findings add further support to the notion highlighted in previous related studies that although perception and action are linked as part of a cycle, what somebody says they 'would do' should not be taken as a proxy for what they would *actually* do (Harris & Wilmut, 2020; Wilmut et al., 2016). Linking this finding back to the constraints-based approach, the difference detected here between perceptual judgement and executed action highlights and adds to the evidence base that these elements of the perception-action cycle are affected differently by individual-, task- and environmental-based constraints including those explored in the current study. More broadly we should consider what it tells use about the potential equivalence between what might be being measured in a perceptual task and what might be being measured in an action task. As stated in the introduction, the ecological approach would posit that action and perception are closely linked and that *"we perceive to act and we act to perceive"* (Gibson, 1979). Removing action from this cycle and requesting a verbal indication of what a person believes they would do may be breaking this cycle and allowing the influence of additional factors to affect the response. On this basis, the lack of correlations between the perceptual and action tasks would therefore support the ecological approach, and potentially call into question the extent to which perceptual judgements are an appropriate way to measure influencers of action.

Limitations in the current study related principally to the nature of measurement in the case of certain wellbeing and movement variables. There are several methods for calculating critical ratio, each of which have strengths and drawbacks. One issue in the current study was the tension between obtaining the most accurate measurement of critical ratio in the different task conditions and the need to be able to compare critical ratios, measured in a consistent way, across those different task conditions. The method used to calculate critical ratios in all task conditions (static perceptual judgement, dynamic perceptual judgement and executed action) allowed comparison of the perceptual judgement (both static and dynamic) and executed action critical ratios with each other. However, the nature of the perceptual tasks was that the data collected was categorical and therefore lacked the richness of the movement data where we were able to measure safety margin. This richer data may have made it possible to unpick the nuances in relationship between anxiety and movement in a way that was not possible when using the categorical data.

This is also a broader issue in the field of perception and action research in terms of comparing critical ratio findings across studies. The debate surrounding methods for calculating critical ratio also highlights the further clarity afforded by the measurement of relative safety margin as a complementary or alternative measure of movement behaviour within the context of this task paradigm. Another measurement-related limitation was the nature of using questionnaire-based measures of anxiety. In light of the earlier point regarding the detection of a relationship between movement-specific anxiety and movement behaviour, a physiological measure of anxiety could be a more sensitive and accurate tool to detect and offer greater insight into the relationship between anxiety and movement behaviour.

In conclusion, the results of the current study suggest that, within a typically developing adult population, higher anxiety related specifically to movement on foot around an everyday environment leads to individuals leaving more space beyond their own body width when navigating through apertures. Although this relationship was evident in the movement behaviour itself, it was not evident in perceptual judgements about this same movement behaviour. The results also indicate that the point at which behaviour changes, the critical ratio, differs significantly between perceptual judgement when standing still (what individuals said they 'would' do) and executed action (the movement behaviour individuals actually performed). Together these findings further illustrate that perception and action must be studied together before drawing conclusions based on one or the other alone since they may be influenced by differing constraints. They additionally reveal the importance of measurement tool specificity in being able to capture specific and nuanced relationships between wellbeing factors and the perception-action cycle that may go undetected with the use of more generalised measures.

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Compliance with ethical standards

The research undertaken in this study, including all procedures involving human participants, was performed in line with the principles of the Declaration of Helsinki. As has also been stated in the main text at the end of the Methods section, approval was granted by the University Research Ethics Committee of Oxford Brookes University (UREC reference number: 201422).

Consent to participate statement

Informed consent to participate, and to publish data and findings resulting from their participation, was obtained from all individual participants included in the study.

CRediT authorship contribution statement

S. Harris: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **C.J. Rathbone:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **K. Wilmut:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

Data availability

Data from this study will be made available on the Open Science Framework (OSF) on publication of the manuscript.

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