Coaxing: An Empirical Exploration of a Novel Way to Nudge Athletic Performance in Sports

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Abstract. This paper presents design work and empirical work, exploring a novel way of steering player behaviour and performance in sports, called 'coaxing'. We propose that athletic performance might be influenced by tricking players into thinking that their athletic abilities are different from what they really are. We approach this proposition from three different angles. First, we use related work to theoretically ground the concept of coaxing in literature. Second, we take a research-through-design approach to illustrate the potential of coaxing for sports practice, specifically volleyball. Third, we carried out an experimental study to shed light on the effectiveness of coaxing, also in the context of volleyball. For the experimental study, we explored the idea of coaxing by means of an augmented ball-catching task. For every participant, we quantified their ability to intercept fly balls and presented them with visualisations that either overstated or understated this ability; in the expectation that this would impact how they acted in the ball-catching task. While the effects of coaxing failed to reach significance, data suggest that coaxing might yet be a viable form of steering player behaviour. Contrary to our hypothesis, participants whose abilities had been understated mostly outperformed their counterparts. We discuss the particularities of the current findings and their implications for sports practice. We conclude with practical and theoretical recommendations to further develop the concept of coaxing.

Keywords: Steering behaviour · Coaxing · Perceptual-motor training · Augmentation · Sports interaction technology · Sports · Volleyball · Nudging

1 Introduction

Sports and technology are getting ever-more intricately linked: activity trackers are standard issue when going for a run; augmented reality is within reach when shooting ball, and sports apparel ensures optimal thermal-regulation when exercising. Technology is omnipresent and shapes the way athletes train and perform.

N. Baghaei et al. (Eds.): PERSUASIVE 2022, LNCS 13213, pp. 174–189, 2022.
https://doi.org/10.1007/978-3-030-98438-0_14

It is even contended that technology might be the main driving factor behind athletic performance in the future [38].

The Olympic motto taps into this focus on athletic performance: with *'Faster, Higher, Stronger - Together'* the Olympic founder Pierre de Coubertin wanted a slogan to emphasise excellence [5]. Recognising the apparently important role that recorded performance plays, in this paper we start with looking into a possible strategy to improve athlete's performance using 'persuasive' technology.

The field of SportsHCI not only aims to perfect performance; the unbridled potential of interaction technology for sports comes to light when also considering the many other application domains that it caters to, for example: entertainment [13,15,33,62], refereeing [3,4,10]; safety [1,2]; training [22,27,31,32,39,40,51,59] and research [11,59,64]. And this is just painting the picture in broad strokes. Zooming in on 'training' for example, systems have been developed that foster engagement [35,47,49,73], and accelerate learning [8,14,26,29,39,40,60], with even finer distinctions made for the different skill domains, such as physical [50], technical [54,65], tactical [22] and perceptual-cognitive [16,22,31,40,60,61].

For the current contribution, we capitalise on the visual nature of an interactive floor [56] to explore a novel game mechanic for steering player behaviour and performance in sports, which we call 'coaxing'. In this regard coaxing is tricking athletes to perform better by misrepresenting their capabilities. In Sect. 2, we present an investigation of how the concept of coaxing is theoretically situated within the fields of ecological psychology and persuasion. In Sect. 3 we present design work to illustrate the various applications of coaxing for (volleyball) practice. Specifically, we present four training game concepts that make use of coaxing to support volleyball players in their practice. In Sect. 4 we present empirical work to investigate the effectiveness of coaxing. Together, these sections investigate the potential of coaxing for sports.

For our experimental study, we present players with an altered visual representation of their motor abilities to trick them ('coax' them) into thinking their action capabilities are either greater or poorer than they actually are, causing them to over or underestimate their abilities. We tested this idea with a ball catching task, derived from the serve-reception task in volleyball. Players were presented with a range of ball trajectories, pitched towards them at various angles. For each ball angle, we determined the greatest distance that the player could cover within the flight time of the ball (their factual action boundary) and manipulated this area in order to visually represent either a smaller-than-actual 'action boundary' (0.75x) or a greater-than-actual 'action boundary' (1.25x) to the player, under the guise of showing them their factual 'action boundary' for catching fly balls (see Fig. 3). We hypothesised that participants in the 1.25x-group would intercept more balls than their counterparts in the 0.75x-group.

2 Related Work

To explore coaxing, we ground the concept in related work in two ways. First, we develop the concept by considering the fundamental principles of Ecological Psychology, specifically focusing on the concept of *affordances* [24]. Second, we situate the concept of coaxing within its broader theoretical framework of steering and persuasion.

2.1 Affordances

From the perspective of Ecological Psychology, it is contended that people perceive the world in terms of what they can or cannot do. That is, people perceive the world in terms of their action possibilities, known as affordances [24]. Which action possibilities are manifest in any given situation depends on the relationship between the behaviourally relevant properties of the athlete's action system on the one hand and the behaviourally relevant properties of the environment on the other hand [69]. Put into concrete terms: a ball affords catching to a player whose abilities are such that the demands imposed by the flight-trajectory of the ball can be met (e.g. in terms of speed and direction) [57]. In the present study we aim to influence catching performance by providing players with an altered representation of their own locomotor abilities, thereby subtly adding to the extant agent-environment factors that relate to form the affordance of catchability.

Many studies have set out to examine how people respond to changes in the agent-environment system [17–21,24,28,36,43,45,52,57,69,70]. People can adapt quickly when imposing changes on their (motor) abilities. In braking a car to a safe stop for example, people quickly recalibrated when their brake-strength had been adjusted [17–19]. The same phenomenon has been shown to occur for instance in sitting and stair climbing [43]. Though, in all of these studies, *actual changes* had been made to the (motor) abilities of the agent. The present study is unique in the sense that it presents participants with *feigned, covert changes* to their motor abilities. Here, we investigate the influence that such changes might have on motor performance and how such changes might be leveraged for training purposes.

2.2 Approaches to Steering Behaviour

Steering can be considered to fall under the umbrella of 'Procedural Persuasion'. With procedural persuasion referring to "*...the interpretations addressed by the rules of the persuasive game between visual, haptic, sonic and linguistic representations which guide players' interpretation.*" [12]. Steering differentiates itself from many forms of persuasion in the approach that is taken to influence behaviour. Whereas truly persuasive technologies set out to willingly and transparently persuade the user [63], steering can involve users to be deceived, coerced or unknowingly influenced in their behaviour (all supposedly with benevolent intentions). Building on the conceptual model of de la Hera Conde-Pumpido on persuasive game structures, Fig. 1 presents a high-level conceptual overview of how steering in general and coaxing in particular relates to persuasion.

'Coaxing' as a method to interactively steer behaviour adds to a family of existing approaches that include 'require', 'insist' and 'entice' [68]. Whereas coaxing takes a gentle yet persistent approach to steering behaviour, 'require' is much more forceful. In the latter, an agent is literally *required* to take a certain course of action in order for the game to work as intended. ‘Insist’ is more lenient in the sense that the game works as intended even if the player does not act as insisted, however not doing so might give the player distinct disadvantages. An archetypal example of the ‘insist’ approach is to provide players with game outcome related rewards in the form of ‘power-ups’. The final and least forceful of the three approaches is to ‘entice’ players to act in a certain way [68]. Typically, enticement is done by providing players with rewards that have intrinsic value, but no game-outcome related value, for example by providing players with upgrades in the appearance of their avatar. ‘Coaxing’, as explored in this study, adds to these approaches. Arguably, coaxing is the most subtle and covert way to steer behaviour which might be an advantageous trait in the context of skill balancing cf. [23].

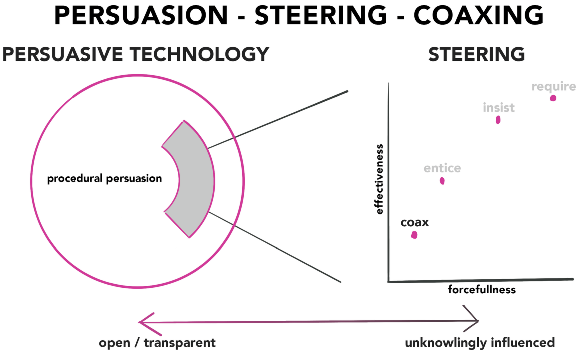

Fig. 1. Coaxing embedded in its broader theoretical context of steering and persuasion.

3 Illustrating Coaxing Through Concept Designs

To investigate the potential value of coaxing for sports practice, we adopted a research-through-design approach. We designed four distinct implementations of the coaxing concept for volleyball practice (see Fig. 2) and evaluated their potential benefits by means of formative user testing. Specifically, we used Design Thinking [37], iteratively cycling through its various stages, to arrive at fruitful applications for volleyball training. In doing so, we consulted 8 trainers and 15 players from 4 different sports clubs. In earlier stages of design, we presented our target-audience with lo-fi digital prototypes with which they could (digitally) interact while in later stages we also tested hi-fi prototypes using an interactive LED floor, see: [56]. Not all participants were confronted with all prototypes. Below, we briefly describe four of the most promising concepts that emerged from our design process to illustrate how the theory behind coaxing might find its way to practice.

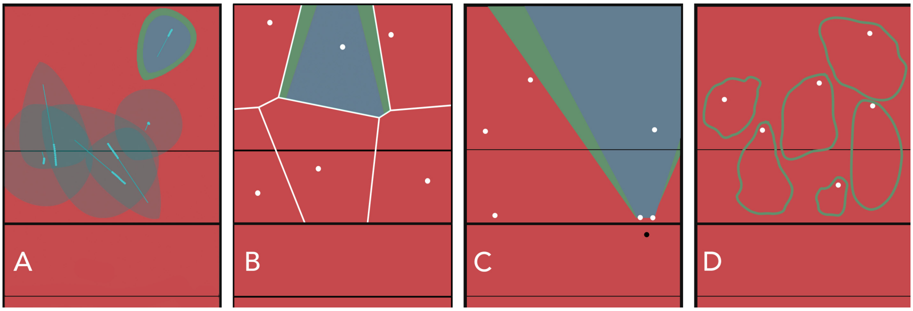

Fig. 2. Four different implementations of coaxing through visual manipulation in the context of volleyball. Blue surface areas represent players' factual motor abilities; green surface areas represent how such abilities might be (visually) overstated - coaxing players to perform differently. (Color figure online)

Figure 2A presents a coaxing strategy around '(mis)representing a player's action boundaries', much similar to the manipulation that we set out to empirically test in Sect. 4 (see also [56] for more information). Figure 2B uses Voronoi diagrams as a means to coax player behaviour. The Voronoi cells show for any given player which area of the field is closer to them than to any other player. The mathematical concept is commonly used in sports performance analysis to indicate what players are responsible for which parts of the playing field, based on their relative positioning [42,53]. Using this to our advantage, the individual Voronoi cells could be misrepresented visually (i.e., expanded or contracted) to steer behaviour. Figure 2C shows, what is colloquially known as, a 'block shadow'. The block shadow is that part of the field that is shielded off from a direct hit from a spike by 'the block' (involving up to three players). Visualising the block shadow might help players cover the field more effectively. This effect might be enhanced by expanding or contracting the factual block shadow, coaxing players to veer from or move towards the block shadow. Finally, Fig. 2D illustrates a variant of coaxing wherein the trainer or coach is free to draw (misrepresented) shapes on the floor. These custom shapes might be pinned to individual players and are scaled proportionally relative to their kinematic characteristics. This variant is especially useful to capture the many idiosyncrasies that come with defensive tactics in volleyball. From user tests with this prototype it was learned that (expert) players have very outspoken notions of accountability and positioning when it comes to defending certain parts of the field.

Both players and trainers were enthusiastic about these four training concepts. They affirmed that the concepts were relevant for volleyball practice and that they might have merit for training. Players and coaches considered the coaxing elements interesting, however they were uncertain whether the coaxing approach would lead to notable training effects. In what follows, we present an experimental study to investigate the effectiveness of coaxing in nudging athletic performance.

4 Investigating Coaxing in an Experimental Task

To study the effects of coaxing on athletic performance, we designed a ball-catching task. We aimed to influence catching performance by visually misrepresenting participants' abilities to make a catch, see Fig. 3.

4.1 Methods

Participants. Twenty-six participants were recruited for a ball-catching task. Participants were between 19 and 59 years of age (M = 27.9 years; SD = 10.3) and were experienced in playing ball sports (*M = 8.8 years; SD = 8.0*). The experiment was approved by the ethical committee of Electrical Engineering Mathematics and Computer Science (EEMCS) of the University of Twente (RP 2019-16).

Setup and Apparatus. An interactive installation was built to systematically test and manipulate participants' performance in a fly-ball catching task. Using digital image projection in combination with motion capture, an interactive ground surface was created with visualisations responsive to player motion. The visualisation showed a boundary at a certain distance around the participants, of which they were told that this represented their 'action boundary' (i.e. the maximum distance at which they supposedly could catch a ball thrown at them).

A ball projection machine (Lobster Elite Liberty) was used for consistent ball delivery. Vertical ball projection angle and release velocity were kept constant, resulting in ball trajectories with a flight time of 1.40 s, with the ball travelling 6.65 m. The positioning of the ball pitching machine and the horizontal ball projection angle were varied to hit different targets (see Fig. 3). The pitching machine proved to be consistent in ball delivery (*SD = 0.09* m). The pitching machine was hidden from sight.

We used the software and the setup from [46], using four top-down Kinects, two PCs, and two high-end projectors to track players in a 5.3 m by 5.3 m interactive projection field.

Quantifying Action Boundaries. In order to present players with an *altered* visualisation of their ability to intercept fly balls, their *factual* ability had to be quantified first. To quantify the *size* of a player's locomotor range, a macro-dynamical model on sprint running was instigated [55]. The model, specifically developed for the case of catching fly balls, calculates locomotor range based on the maximal running speed and acceleration of the player and the time that is available for ball interception. Players' maximal running speed and acceleration were obtained with the help of the playground's trackers.

To quantify the *shape* of a player's locomotor range, a pilot study was performed. We measured for one participant the greatest distance that he could cover in 1.40 s for targets placed at various angles (i.e. −90° to +90°). Performance was sampled multiple times, in steps of 15°. It was found that, by and

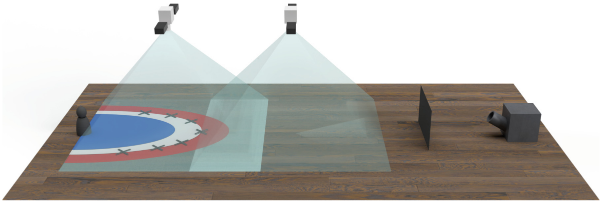

Fig. 3. Illustration of the experimental setup. From left to right: the participant, kinects and projectors, occlusion screen and ball projection machine. The white semi-circle represents the participant's factual locomotor range; the blue semi-circle the smaller-than-actual locomotor range (−25%) and the red semi-circle the greater-than-actual locomotor range (+25%). All fly balls were projected *at* the boundary of a participant's locomotor range (black cross marks). (Color figure online)

large, target angle had no effect on locomotor range. The greatest distance that could be covered was roughly the same for all targets. As such, we decided to represent players' action boundaries as semi-circles, with a radius that reflected their locomotor abilities (Fig. 3, white semi-circle).

Manipulating Action Boundaries. To provide players with an altered representation of their locomotor abilities, we applied a linear transformation to their quantified locomotor range. Participants were provided with a 25% smaller-than-actual locomotor range (in Fig. 3 the blue semi-circle) or a 25% greater-than-actual locomotor range (in Fig. 3 the red semi-circle).

Experimental Design and Procedure. To examine the effects of coaxing on performance, participants were tested in a two-group between-subjects design. Participants were randomly yet evenly divided between two groups: a 0.75x-group and a 1.25x-group. The altered visualisations were presented to the participants throughout the experiment, but not *during* a trial. This was done to minimise the risk of participants finding out that the projected action boundary in actuality did not represent their *true* action boundary.

It is important to note that for every participant, regardless of which group they were in, fly balls were projected *at* the border of their *factual* action boundary, not at the border of their *altered* action boundary. Participants received a total of 21 trials (7 targets, 3 repetitions). The targets varied in projection angle, ranging from −60° to 60°, in steps of 20° (indicated by the black cross marks in Fig. 3). Trials were presented in a block-randomised order.

Right before the start of a trial, the experimenter verbally cued the participant to get ready. Participants were emphatically instructed to intercept as many fly balls as possible. Interception was considered successful whenever a participant caught or touched the ball before it hit the ground (participants were not made aware of this definition). After the experiment, participants completed a questionnaire inquiring about their experiences with the experiment

Data Analysis. A number of measures were obtained to investigate the effects of coaxing on player behaviour. At the start of the experiment, maximal running speed, maximal running acceleration and locomotor range were determined from the tracker data. Besides these kinematic qualities, 'running distance' was determined from the tracker data for every trial. Running distance was the distance that a participant had covered during a single trial while running to make a catch[1]. To make 'running distance' more meaningful, we normalised running distance by dividing it by locomotor range. With values smaller than 1 signifying that the distance travelled was smaller than the locomotor range of the participant and values greater than 1 signifying the opposite. We call this variable '*normalised running distance*'. In addition, we measured participants' response time on the basis of off-line, post-hoc video analysis.

For this study, we set out to examine whether 'coaxing' would influence player behaviour and performance. Specifically, we were interested to know a) whether coaxing would influence catching performance and b) whether coaxing would influence (normalised) running distance. To address these issues, we performed *mixed effects regression* analysis, see: [34,66,71,72]. The data were analysed using the lme4-package [9] of the R-software package [58]. We modelled the random-effects structure and started out with an intercept-only model. A step-wise forward selection approach was used to add predictors to the model. Two separate models were constructed to investigate the effects of *condition* (0.75x vs 1.25x) on 'normalised running distance' and 'catching performance', respectively. A Bonferroni correction was applied to mitigate the effects of multiple testing.

4.2 Results

Normalised running distance was modelled using *Linear* Mixed Effects Regression. It was found that the best possible model to explain the variance in 'normalised running distance' did not include 'condition' as a significant predictor. Since our primary motive is to investigate the effects of coaxing and not to characterise 'normalised running distance' per se, we will dispense any further discussion about the modelling of 'normalised running distance'.

Catching performance was modelled using GLMER. It was found that the best possible model to explain the variance in 'catching performance' involved 'condition' as a significant predictor (though see Sect. 4.2). Table 1 presents a list of the significant (interaction) effects involved in our final model specification.

Because our main focus is on understanding the effects of coaxing, and not on modelling 'catchability' per se, we will limit our discussion of the model specification to the effects relevant to coaxing (that is, the first-order interaction effect of *manipulation* × *normalised running distance*, see Fig. 4).

Condition, moderated by *normalised running distance*, showed to be a significant predictor for 'catching performance' in running to catch fly balls. Figure 4

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[1] The measurement of *running distance* required manual operation of the Playground trackers. Data recording from the trackers was initiated right before ball projection and manually stopped when either the ball hit the floor or when the participant contacted the ball.

Table 1. Fixed effects structure (top) and random effects structure (bottom) of the mixed effects regression model for predicting ball contact

fixed effects (z-transformed)	est. (log odds)	SE	Z	p[1]	95% CI	random effects	var.	95% CI
intercept	2.804	1.169	2.399	0.016	0.614 – 5.346	participant	0.75	0.314 – 1.127
trial number	0.250	0.121	2.076	0.038	-0.012 – 0.513	trail id	0.22	0.000 – 0.750
max velocity (m/s)	0.750	0.254	2.951	0.003	0.237 – 1.264			
ball angle (deg)	0.132	0.285	0.463	0.643	-0.412 – 0.751			
distance (dist / AB)	2.097	0.765	2.742	0.006	0.658 – 3.942			
manipulation (type 1.25)	-1.292	0.891	-1.451	0.146	-3.168 – 0.486			
experience (experienced)	-0.185	0.598	-0.309	0.757	-1.502 – 0.920			
trial number × max velocity	-0.391	0.121	-3.229	0.001	-0.661– -0.157			
ball angle × distance	0.376	0.140	2.682	0.007	0.092 – 0.688			
distance × manipulation	-1.639	0.683	-2.399	0.016	-3.229 – -0.299			
ball angle × experience	-0.680	0.259	-2.625	0.009	-1.316 – -0.179			

[1] p-values smaller than 0.025 are considered significant ($p=0.05$, Bonferroni $n=2$)

shows that the odds of making a successful catch increase with normalised running distance, but differently so for the 0.75x-group and the 1.25x-group. Participants that were presented a smaller-than-actual action boundary performed worse than their counterparts when the distance covered was relatively short (i.e. a distance shorter than 0.65× their locomotor range). Conversely, participants that were presented with a smaller-than-actual action boundary performed better than their counterparts when the distance covered was relatively great (greater than 0.65×). On average, the 0.75x-group successfully intercepted the ball 76.9% of the times while the 1.25x-group intercepted the ball successfully 69.9% of the times. Overall, the model captured 79.08% of the variability in catching performance (sensitivity = 80.82%; specificity = 69.88%).

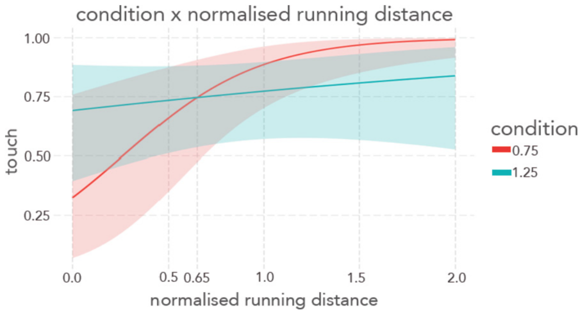

Fig. 4. Partial effect condition x normalised running distance

Model Criticism. We performed outlier-analysis on the basis of Z-transformations to investigate the influence of potential outliers on the fit of the model. It was found that a small group of outliers for normalised running distance (with absolute Z-values greater than 3) might have impacted the fit of the model. Although there is no strong theoretical reason to not allow for extreme values in normalised running distance, it seems fair to assume that participants would not have been able to cover distances thrice their measured locomotor range or more. As such, we investigated how the removal of such extreme values would influence our findings. It was found that the effect of *condition* × *normalised running distance* was no longer significant ($p = 0.222$) when values with an absolute Z-score greater than 3 were removed. So, at least in part, the significant effect for normalised running distance × condition seemed to be carried by this group of outliers.

Finding that the present results are not unambiguously significant prompts further inquiry. To make the data more tangible, we calculated the *Average Marginal Effects* and the marginal effect of condition (i.e. *discrete change*) on catching performance as a function of normalised running distance for the trimmed model.

Marginal Effects. Average Marginal Effects, or AMEs, specify how a one-unit change in one of the independent variables affects the dependent variable on average [41]. Figure 5 provides the Average Marginal Effects with 95% confidence intervals for the trimmed model. From the confidence intervals it can be observed that the estimated AME falls between −19.32% and +4.70%. While helpful, AMEs tell a limited story as they represent an average. To further unpack the Average Marginal Effect for condition, we plot the marginal effect of condition (i.e. *discrete change*) on catching performance as a function of normalised running distance (Fig. 5) with 90% confidence intervals. This figure shows the discrete difference between the 0.75x-group and the 1.25x-group for increasing values of normalised running distance on the predicted probability of making a successful catch. Regions where the confidence bands do not include the null-line represent the range of values for 'normalised running distance' where 'condition' has a marginal significant effect on 'catching performance' (i.e. $p < .10$) [41]. From Fig. 5, it can be seen that the effect of 'condition' is indeed *marginally* significant for values of normalised running distance greater than 0.65 and smaller than 2.5 (i.e. the 90% CI, does not include the null-line for that value range).

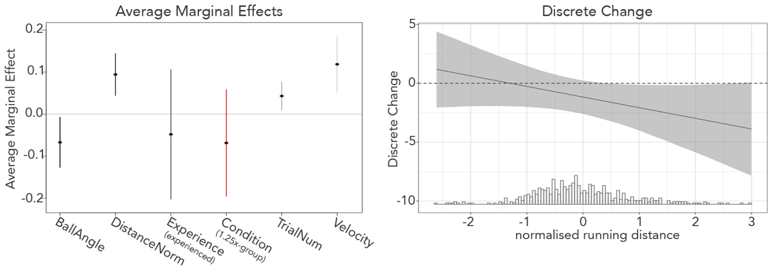

Fig. 5. Plot showing the Average Marginal Effects (right) and a plot showing the marginal effect of condition (i.e. *discrete change*) on catching performance as a function of normalised running distance (left). Both graphs are based on the trimmed model.

5 Discussion

The results of the present study show that coaxing is versatile in its application and that coaxing might potentially be a fruitful way to influence player performance in sports. The results from the experimental study however are not unambiguous. In this section, we will discuss and interpret the particularities of our empirical findings; reflect on the value of coaxing for balancing game play; and make suggestions for further research.

5.1 Interpreting the Results of Coaxing

The most important finding in the present study was that the effect of condition on catching performance was marginally significant when participants had reached or exceeded approximately half their locomotor range. Interestingly, the effect of coaxing favoured the 0.75x-group. Participants in the 0.75x-group intercepted more fly balls than their counterparts in the 1.25x-group. This was different from what we had hypothesised. Our initial hypothesis was that participants that were shown a greater-than-actual action boundary would perform better than participants that were shown a smaller-than-actual action boundary. However, the reverse appeared to be the case. To understand why this might be; we turned to the results from the post-experimental interviews.

Based on the semi-structured interviews, participants generally thought that the action boundaries nicely represented their actual capabilities. However, when prompted, most participants were able to indicate whether their action boundary had been reduced or extended. Interestingly, one participant from the 0.75x-group indicated that his action boundary motivated him to push further *"I tried to reach past the [action] boundary, this motivated me to push myself harder"* (P04). He added: *"though I do think that it really depends on the person, some people might be challenged by the visualisations, whereas other might take them for fact"*. This is an interesting statement – coaxing might potentially act on players' motivation, thereby influencing their performance.

5.2 Running Towards Effective Coaxing Experiments

Clearly, the present results do not paint the definitive picture on the effectiveness of coaxing. Additional research is needed to prove the potential of coaxing in steering player behaviour. In future research, we aim to investigate the role of coaxing in a less complex task environment. Running might be ideally suited for this. The recent introduction of the WaveLight system in athletics[2] has caused many world records to be shattered. It has been hypothesised that psychological factors such as motivation might have had a role to play in that (besides better pacing) [44]. As such, focusing on running in combination with the WaveLight system might provide us with a simpler yet more relevant experimental setting to investigate the effects of (and the mechanisms behind) coaxing.

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[2] https://www.wavelight-technologies.com.

5.3 Hidden Balancing

The results from our empirical study suggest that coaxing might potentially be interesting in the context of *hidden balancing*. Balancing techniques in (interactive) games and sports have been studied extensively [6,7,23,25,30,48,67], and with good reason. Besides the apparent effects on game-outcome, proper game balancing has been associated with increased levels of fun, engagement and self-esteem (ibid.). The experiences with *implicit* balancing have been positive in that regard. Gerling and colleagues for example, explored hidden balancing strategies (i.e. time balancing and score balancing) [23]. They showed these hidden balancing techniques to promote self-esteem while decreasing the score differential. Coaxing adds to these techniques, potentially enabling interaction designers to promote game balance through the way players perceive their own abilities.

5.4 The Ethics of Coaxing

As we put it before, coaxing is about ‘tricking’ people into believing their abilities are different from what they truly are. As such, coaxing might potentially impact the way athletes perceive and value their own abilities. When applying coaxing, designers should be careful not to hurt athletes’ self esteem and body image. Also, coaxing, once uncovered, might undermine the authority of the trainer/coach. So, even with benevolent intentions, coaxing should be used with care.

6 Conclusion

In the present contribution, we introduced the concept of ‘coaxing’ as a novel form of behaviour steering; defined it in relation to existing forms of persuasion; designed implementations for volleyball practice; and explored its effects empirically. While the empirical results came out inconclusive, the results hinted towards its possible effectiveness. Furthermore, from post-experimental interviews, it was found that coaxing might influence player motivation: Players might feel challenged by what the technology is telling them about their abilities. In future research, the effects of coaxing need to be investigated further to shed light on its potential for training.

Acknowledgements. This research was partially made possible in the context of the national funded ZonMW *Smart Sports Exercises project* - grant number 546001004, and would not have been possible without the support of all athletes, trainers, and experts who contributed to our activities. We would like to thank the DreamTeam of the DesignLab at the University of Twente who facilitated our experimental work.

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