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Highlights

- A modified ball – futsal ball - promoted transfer of passing skill to a standard ball
- Practicing passes with the modified ball encouraged changes in participants' gaze behaviour
- The changes in gaze behaviour underpinned positive transfer of the passing skill
- Practitioners working in soccer are encouraged to use this modified ball to promote their athletes' skill development

Abstract

Objectives: Equipment is frequently modified to promote skill learning in sport. However, it is unclear whether skills learned using modified equipment transfer to the criterion task. This study examined the transfer of passing skill from practicing with a futsal ball to performing with a soccer ball, and the perceptual skill underlying the process.

Methods: 24 adult novices (n=18 females and n=6 males, 24 ± 4.8 years old) were divided into an experimental (FUT) and a control group (SOC). The two groups practiced the same passing skill in response to video stimuli across 3 sessions, the FUT group used a futsal ball and SOC group used a soccer ball. Passing performance and gaze behaviour were assessed pre- and post-intervention using a soccer ball in both groups to evaluate transfer.

Results: FUT showed greater pre- to post-test improvement (Effect Size (ES) = 2.06 ± 0.86) in passing performance than SOC (ES = 1.03 ± 0.82), and higher passing performance in a time-constrained scenario in the post-test (ES = 1.83 ± 1.07). The higher passing performance in FUT was underpinned by changes in gaze behaviour. FUT increased the number of fixation alternations between the ball and other locations and changed the cues learners focused their attention on, while SOC only slightly modified their gaze behaviour.

Conclusions: This study showed that modified equipment – futsal ball – shaped the development of a behavioural repertoire that positively transferred to other equipment – soccer ball – improving learning of a perceptual-motor skill. Practitioners working in soccer are encouraged to use a futsal ball in their training sessions to fast-track learning, particularly in novices.

Keywords: skill acquisition, skill adaptability, task constraints, modified sport, gaze behaviour, football

Introduction

The characteristics of equipment, such as ball compression and bat dimensions can be modified to simplify the execution of sport skills in children or in novices, potentially fast-tracking the learning process (Araújo, Davids, Bennett, Button, & Chapman, 2004; Farrow, Buszard, Reid, & Masters, 2016). Buszard, Reid, Masters, and Farrow (2016b) recently illustrated in their systematic review the psychological, biomechanical, cognitive, and skill performance factors that can be promoted using modified equipment, and also highlighted a lack of transfer studies which limits the current understanding of how modified equipment influences skill learning. Furthermore, previous research has mainly assessed the physical aspects of performance, e.g., number of skill executions (Farrow & Reid, 2010) and fluency of movement (Buszard, Reid, Masters, & Farrow, 2016a), while the perceptual side of performance has remained relatively un-explored. As such, it is currently unclear whether skills learned with modified equipment transfer to tasks that employ other equipment (e.g., standard equipment) and how the underpinning perceptual skill is affected.

Skilled behaviour emerges from the coupling of perception and action under the interaction of organismic (e.g., action capabilities and intentions), environmental (i.e., features of the environment), and task (e.g., equipment) constraints (Araújo & Davids, 2011; Kelso, 1995; Newell, 1986). Opportunities for action (i.e., affordances) emerge from the the performer-environment interaction (Gibson, 1979; Newell, 1991). The perception of information specifying affordances regulates decision-making and the self-organisation of coordination patterns (Araújo, Davids, & Hristovski, 2006; Davids, Button, & Bennett, 2008b). In this sense, perception, cognition and action are intertwined processes that underpin an individual's skill (Araújo et al., 2006; Araújo, Hristovski, Seifert, Carvalho, & Davids, 2017).

Transfer of skill in this context, refers to how previous exposure to a particular set of interacting constraints influences task performance under different constraints (Newell, 1996; Rosalie & Müller, 2012; Seifert et al., 2016). Skill transfer is evaluated on performance achievement (i.e., the degree of success when performing a task; Araújo & Davids, 2015), and is considered positive when previous practice leads to a performance improvement under a new set of interacting constraints (Carroll, Riek, & Carson, 2001). Positive transfer occurs due to the due to the similarity between a practiced behaviour and the functional perception-action coupling required in a new task (transfer) to achieve the task goal (Newell, 1996; Pacheco & Newell, 2015).

A modification to equipment, which is a task constraint, influences how perception, cognition, and action emerge (Araújo et al., 2004). Practicing with a piece of equipment shapes how individuals educate their attention towards the information that specifies affordances, and how they self-organise coordination patterns (Davids et al., 2008b). The skill learned with a specific piece of equipment can positively transfer if the developed behaviour cooperates with the new task constraints (e.g., different equipment) (Kelso & Zanone, 2002; Zanone & Kelso, 1997). Put simply, an equipment modification that facilitates perception (cognition) and action coupling in a new task promotes transfer. Similarity of the information that guides action between the learning and transfer tasks promotes the transfer process (Pinder, Davids, Renshaw, & Araújo, 2011; Snapp-Childs, Wilson, & Bingham, 2015). The influence of equipment on the transfer of perception and action is relatively un-explored in the human movement field; the current study examined how modifications to equipment influence the transfer of passing skill from a futsal ball to a soccer ball.

The passing skill in soccer is a complex perceptual-motor skill that involves making a decision, on who to pass a ball to, and kicking the ball towards a teammate (Oppici, Panchuk, Serpiello, & Farrow, 2017). Perception, decision-making and the passing action are intertwined and emerge from the interaction of a passer with their environment and the characteristics of the task. A successful pass entails perceiving information specifying affordances (e.g., distances and angles between players; Travassos et al., 2012) and organising a functional kicking action to successfully kick the ball to the intended player. The analysis of eye movements can be used for examining attentional processes that underpin passing, due to the partial-interdependence of attention and eye movements (Dicks, Button, & Davids, 2010; Van Gompel, Fischer, Murray, & Hill, 2007). Gaze patterns provide information on individuals' attunement to environmental information, and provide insights into changes in perceptual skills (Panchuk, Vine, & Vickers, 2015). For example, previous research has showed that frequent switches of attention between the ball and players underpinned successful passing performance in soccer (Vaeyens, Lenoir, Williams, & Philippaerts, 2007).

Futsal (FB) and soccer (SB) balls are used in futsal (the 5-a-side form of football) and soccer (the 11-a-side form of football) respectively, and they are likely to influence how the passing skill emerges. Both balls (i.e., FB and SB) are spherical but differ in size, circumference of 63 and 69 cm, weight, 420 and 430 gr (FIFA, 2010), and coefficient of restitution, 0.51 and 0.60 (Peacock, Garofolini, Oppici, Serpiello, & Ball, 2017). While previous research showed that, in a group of young athletes, practicing futsal or soccer exclusively influenced the perceptual skill underpinning passing (Oppici et al., 2017), the effect of the different balls alone on the passing skill is unclear. Futsal balls are thought to be easier to handle due to a higher energy loss during foot-ball impact (due to the lower coefficient of restitution) that prevents FB from bouncing off the foot uncontrollably (Araújo et al., 2004; Peacock et al., 2017).

Equipment that simplifies the execution of a skill promotes skill automaticity (i.e., execution with little or no involvement of attention) (Buszard, Farrow, Reid, & Masters, 2014), which, in turn, has been shown to facilitate the education of attention towards information specifying affordances (Mackenzie & Harris, 2017). Therefore, practicing the passing skill with a FB is expected to promote the development of more efficient perception-action coupling relative to a SB, and the behaviour developed is expected to transfer to passing with SB due to task similarity. While previous research (Travassos, Araujo, & Davids, 2017) and anecdotes from elite soccer players (UEFA, 2014) have suggested that practicing with a FB fosters the development of passing skill in soccer, implying the transfer of skill, this issue has not been investigated.

The aim of this study was to determine the transfer of passing skill from practicing with a FB to performing with a SB, and the perceptual skill underpinning it. The passing skill of adult novices, who trained with a FB for 3 sessions, was evaluated against a control group who trained with a SB. Pre- and post-training assessments were performed using a SB in both groups to evaluate transfer. It was hypothesised that positive transfer of passing skill from a FB to a SB would be indicated by higher improvement in passing performance for participants training with a FB relative to the SB group, due to the FB's properties and task similarity. The superior performance improvement was hypothesised to be underpinned by development of an efficient perceptual attunement to task-relevant cues, encouraged by a higher level of skill automaticity. FB was predicted to facilitate skill automaticity that, in turn, would promote higher attention alternations between ball and players, lower attention time on ball and higher attention time on players.

Methods

Participants

Twenty-four adult novices (n=18 females and n=6 males, 24 ± 4.8 years old) were recruited for the study. The required sample size was calculated a-priori using G*Power (version 3.1), with a repeated-measures test (within-between interaction), with $\alpha = 0.05$, power $(1 - \beta) =$

0.95, and an effect size of f = 0.42 (derived from similar studies with a similar design; Abernethy, Schorer, Jackson, & Hagemann, 2012; Broadbent, Causer, Ford, & Williams, 2015), resulting in a total sample size of 22 with an actual power of 0.95. Two extra participants were recruited (9% of calculated sample size) to account for attrition.

Participants had no prior experience in organised soccer or futsal (i.e., in a sport club), and their experience in recreational soccer (i.e., kicking with friends or at school) and in other team sports was collected using a customised questionnaire (table 1). The questionnaire included questions on the average hours per week, weeks per year, and number of years of training experience in team-sports and recreational experience in soccer. The participants were divided into two groups, a futsal-ball experimental group (FUT, n = 12) and a soccer-ball control group (SOC, n = 12), after the pre-intervention test using the minimisation procedure, which randomises the allocation of participants minimising group differences (Hopkins, 2010b). Following this procedure, the two groups were matched for their pre-test performance outcome, previous experience in soccer and other team sports (table 1). Participants were informed about the aim of the study but they were blinded with respect to the specific hypothesis.

Prior to the study, participants were fully informed of the risks involved in participating in the experiment and they provided written informed consent to participate. The study was approved by the research team's University Ethics Committee.

******Table 1 near here******

Experimental design

The experimental design comprised of a pre-test, three training sessions, and a post-test (figure 1). The sessions were interspersed by 48 h, and the time of each session was kept consistent throughout the study. Participants were not practicing any team sports at the time of recruitment and were instructed to refrain from engaging in team-sport activities or any additional kicking practice.

Both pre- and post-test sessions were performed with SB in both groups, while the two groups used a different ball in the training sessions (i.e., FUT used FB and SOC used SB). Only FIFA-quality approved balls were used. The SB was a ‘Match’ (Select Sport A.S., Copenhagen, Denmark), inflated at 0.85 atmosphere; while the FB was a ‘Conext15’ (Adidas, Herzogenaurach, Germany), inflated at 0.75 atmosphere. Ball inflation was checked at the beginning of each session, and the inflation values corresponded to the range midpoint specified in the FIFA guidelines (FIFA, 2010).

******Figure 1 near here******

Test and training stimuli constructions

Eight male soccer players (24.4 ± 4.4 years old), who regularly played in regional soccer competitions, were filmed while performing soccer-specific movements on an outdoor pitch to create the experimental video stimuli. A video camera (Panasonic HC-V380K Full HD, Osaka, Japan) was positioned 20 m away from the players, at a height of 1.75 m to approximate a soccer player’s field of view during games. The players were divided into two teams, a red-uniform attacking team and black-uniform defending team, and three different scenarios were created, including 2v2, 3v3 and 4v4. The players, organised in red-black pairs, were instructed to perform set movements, with the red players moving to receive the ball from the investigator positioned behind the camera, and the black players tightly marking their direct opponent. Each trial ended with one of two potential outcomes, either one of the attacking players was unmarked (i.e., his direct opponent stopped following him) or all attacking players were tightly marked. An investigator's verbal signal started the trial, while a second verbal signal indicated the type of outcome.

The footage was then edited using Windows Media Player (Microsoft, Washington, USA) to create decision-making video clips lasting 2.5 s. In each scenario, three different types of clips were created, namely early decision, late decision and no decision. The timing of the attacking player becoming free to receive a pass was between 1.5-1.7 and 2.0-2.1 s for the early- and late-decision clips, respectively, while no attacking player was free in the no-decision clips. The early-decision clips represented an easier challenge than late-condition clips as the teammate was free for a longer period and participants had more time to organise their passing action. Each video clip included, in the following order, a 2-s image of the first frame, a 3-2-1 countdown, the video and then a black screen with red vertical lines corresponding to the final position of the attacking players (figure 2).

Apparatus and procedure

The experimental task involved the participant making a direct pass of a moving ball in response to the video stimuli using the inside part of the dominant foot. The video clips were projected, using a roof-mounted front projector (Mitsubishi XD550U, Tokyo, Japan), onto a screen (4 x 2.5 m). To ensure consistency, the ball was delivered to the participants along the ground through a hole at the bottom of the screen, via a custom-made ramp, positioned behind the screen, that allowed speed to be approximately 2 $m.sec^{-1}$ (Button, Smith, & Pepping, 2005). This task was designed to improve the representativeness of the passing skill in a laboratory setting. While previous research did not consider it (e.g., Helsen & Starkes, 1999; Vaeyens et al., 2007), the reception phase of a pass (i.e., when the ball travels towards the person making a pass) is critical as it challenges an individual's perception of information about ball's and player's behaviour (Oppici et al., 2017; Oppici, Panchuk, Serpiello, & Farrow, 2018).

Pilot trials, where ball speed was indirectly calculated by measuring (from video) the time from the ball exiting the ramp to reaching the spot where participants stood, showed consistency in ball speed in both balls, being 1.96 ± 0.04 and 1.95 ± 0.04 $m.sec^{-1}$ in FB and SB, respectively. The ball delivery and the start of the video were manually coupled, i.e., the ball was released on the '1' of the countdown, with the video starting when the ball passed through the screen hole. The similarity of trial duration in the two groups (2342 ± 123 and 2366 ± 132 ms in FUT and SOC, respectively) indicated consistent video-ball coupling across the two groups.

Participants were instructed to stand on a specific spot, 5 m in front of the screen, wait for the ball and pass it directly (i.e., without controlling it) along the ground towards the free teammate (i.e., red attacking player). The pass had to be directed to the teammate's current position, not to the end-run trajectory. However, participants had to hold the ball when they thought that no teammate was free. After each trial, participants were asked to verbalise their decision saying out loud the number (counting the red lines left to right) corresponding to the teammate they intended to pass the ball to. This was included to assess participant's decision independently from the accuracy of the kick.

******Figure 2 near here******

A Mobile Eye system (Applied Sciences Laboratories, Bedford, MA, USA) was used to collect participants' gaze behavior at 30Hz during the testing sessions. The Mobile Eye uses an eye-tracking technique known as 'Pupil to CR' which correlates pupil and corneal reflection features to compute gaze within the scene being viewed. An external camera (GoPro Hero4, California, USA) was placed in a corner to record participants' performance at 30Hz.

Pre- and post-test

The testing sessions comprised of 24 trials, divided into two blocks of 12, including twelve 2v2 and twelve 4v4 scenarios, in a sequence that was consistent in both sessions across participants. Each scenario included 5 early, 5 late and 2 no decision conditions. The trials were interspersed by approximately 30 s, and no feedback was provided throughout the session.

The sessions started with 20 warm-up kicks towards vertical red lines projected onto the screen. Participants were then fitted with the eye tracker and the system was calibrated using a 9-point reference grid. The calibration was checked between the two trial blocks.

In the pre-test, before the experimental trials, participants were provided with instructions projected onto the screen, that explained the task in detail, and then provided with 10 practice trials to become familiar with the video stimuli and with wearing the Mobile Eye unit.

In the post-test, participants also performed a dual-task kick assessment before the decision-making trials. The dual-task condition involved 10 kicks towards red lines projected onto the screen while simultaneously counting back-wards out loud in ‘threes’ as quickly as possible from a number indicated by the researcher. In each trial, the researcher provided a different number (e.g., 54 or 76) and, after a 3-2-1 countdown, on the ‘go’ signal the ball was released and participants started counting until the ball was kicked. Counting back-wards is a valid stimulus to overload individuals’ attention while performing movements (Buszard et al., 2014). Participants were instructed to perform accurate kicks while counting quickly and accurately, prioritising kick accuracy. Before the dual-task condition, participants performed 10 single-task kicks (i.e., kicking only) and 5 single-task counting (i.e., counting only). The red line positions and number order were consistent across participants.

Intervention

The 3 training sessions comprised of, in the following order, 20 warm-up kicks, a dual-task assessment (same procedure as post-test) and 100 trials, divided in six blocks of 15 trials and one block of 10 trials. The order of trials was different in each session but consistent across participants. The trials included thirty-six 2v2 (16 early, 15 late and 5 no decision), thirty-two 3v3 (13 early, 15 late and 4 no decision) and thirty-two 4v4 trials (9 early, 19 late and 4 no decision). Feedback on the correct decision was provided after each trial. The sessions were filmed using the external camera.

Data analysis

Performance accuracy

Considering that all trials involved a decision but not all of them required a pass, a performance variable was created to capture participant's performance accuracy. Performance accuracy was evaluated by combining decision accuracy and pass accuracy. Performance accuracy provided a measure of performance that balanced potential correct decisions ending with bad kicks, and passes that were accidentally accurate (i.e., participant meant to kick to the wrong teammate but the ball hit the correct player). Decision accuracy was evaluated by comparing the participant's verbal response with the correct decision, while pass accuracy was evaluated in terms of proximity of ball end-point and the free-teammates (i.e., correct decision) final position. The distance between the ball when it hit the screen and the free-teammate position was evaluated by superimposing a grid onto the external-camera video using a free-to-use video-player software (Kinovea 0.8.15). Reference points on the projected video were used to calibrate the grid, which contained 16 spaces, at the beginning of each evaluation. One end of the grid was placed on the final ball position (in the middle of the ball) and the spaces between the ball and free-teammate red line were counted. As such, the lower the distance the more accurate the pass. Performance accuracy was calculated multiplying the participant's decision accuracy by the inverse of average pass accuracy:

*performance accuracy (AU): decision accuracy * 1/average pass accuracy*.

Dual-task performance

Kick accuracy in single- and dual-task conditions was evaluated by superimposing the grid onto the external-camera video, as described in the previous paragraph. As such, the lower the value the more accurate the kick. In both conditions, counting performance was evaluated as quantity of counted numbers, and number of errors in counting, through the performance video. Dual-task cost was calculated in kicking and counting:

dual-task cost (%) = (dual-task performance – single-task performance) / dual-task performance.

Gaze data

The video from the eye tracker and the external camera, both recorded at 30hz, were synchronised using a commercially-available coding software (Quiet Eye Solution, QES) to couple gaze with specific phases during the task (Vickers, 1996). The first frame of the video stimuli was the trial onset and the participant's first contact with the ball (either passing or holding the ball) was the trial offset.

Four gaze behaviours were then coded as fixation, saccade, blink and other. Fixation was coded when the gaze was stable, within 3 degrees of visual angle, on a location for a minimum duration of 100 ms (Panchuk & Vickers, 2006), which corresponds to 3 video frames. Saccade was coded when the gaze shifted to a different area, moving for more than 3 degrees of visual angle, with a minimum duration of 66 ms, while blink was coded when gaze cursor disappeared for a minimum of 100 ms. Lastly, gaze was coded other when vibration of the eye tracking made coding impossible.

Six fixation locations were identified: teammate-opponent pair, ball, free space (area between players, below players' head), free teammate, non-marking opponent (free teammate's direct opponent) and other (area outside the screen or above players' head).

Number of fixations, average fixation duration, fixation order (i.e., the number of fixation alternations between ball and other areas) and relative viewing time (%) in each area of interest were evaluated in each trial.

Percentage transfer

The percentage transfer, from FB training to SB, was calculated for performance accuracy with the formula:

*experimental group – control group/experimental group + control group * 100*

(Magill, 2011), applied to this study:

*FUT – SOC/FUT + SOC * 100.*

Coding reliability

Five percent of the trials were randomly selected and independently coded by two coders, and then re-coded a week later by the primary coder for inter- and intra-rater reliability. Intra-class correlation R values, calculated for performance accuracy, number of fixations and average fixation duration, ranged from 0.93 to 0.98.

Statistical analysis

Performance accuracy, fixation duration, fixation count and relative viewing time were analysed separately using linear mixed modelling with repeated measures (Proc Mixed in Version 3.6 of Statistical Analysis System Studio, SAS Institute, Cary, NC), with group (SOC, FUT) and session (pre, post) as fixed factors and participants as a random factor. The analyses were performed across all scenarios (overall) and in each individual scenario (2v2, 4v4, early, late). Allowance was made for overdispersion. Fixation order was analysed using generalized linear mixed modelling (Proc Glimmix in SAS Studio) with Poisson regression analysis. Dual-task performance across the intervention was analysed using linear mixed modelling with repeated measures, with group (SOC, FUT) and session (S1, S2, S3, post) as fixed factors and participants as a random factor. The between-subject standard deviation for the standardization of the effect sizes was calculated using the pure observed between-subject variance and the overdispersed sampling variance.

Correlations of pre-to-post changes between performance accuracy and gaze variables, and between performance accuracy and dual-task performance, were evaluated separately performing correlation analysis (Proc Corr in SAS Studio).

Significance was set at $p < 0.05$ for all the analyses and the magnitude of changes was assessed using Effect Sizes (ES) with 95 % Confidence Intervals defined as follows: <0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large, >2.0 very large (Hopkins, 2010a).

Results

One participant in FUT did not complete the study and the final sample size included 23 participants, FUT (n=11) and SOC (n=12). Both groups performed the same number of decisions, 300 trials, and kicks throughout the intervention, including warm-up, single-task, dual-task and decision-making kicks, 363 ± 13 and 363 ± 17 for FUT and SOC, respectively. The variability in number of kicks depended on participants' decision, i.e., holding or kicking the ball.

Performance accuracy

There were no statistically significant differences in pre-test performance accuracy (table 1). The analysis of the fixed effects showed a statistically significant session effect overall and in all scenarios ($p < 0.01$); no statistically significant group effect in overall but a statistically significant group effect in the late scenario ($p < 0.01$); a statistically significant group x session effect in the late scenario ($p < 0.01$) and a group x session effect overall ($p = 0.08$). The analysis of least square means differences showed that pre-to-post improvements had a larger effect size in FUT than SOC in all scenarios except the early scenario (table 2). In the post-test, FUT performance was higher than SOC, moderately and largely in the overall and late scenario, respectively. A similar trend was observed when decision accuracy and pass accuracy were analysed separately, that is FUT showed a greater improvement in both decision and pass accuracy than SOC.

******Table 2 near here******

Gaze data

The gaze videos of three participants, one in FUT and two in SOC, were not reliable and they were excluded from the analysis. This resulted in 20 participants (10 per group) included in the analysis of the gaze data.

Fixation count. The analysis of fixed effects did not show any statistically significant session, group or group x session effects. The analysis of least square means differences only showed an effect in SOC in the 2v2 scenario ($p = 0.08$, ES = 0.84 ± 0.94), with the group decreasing the number of fixation pre to post.

Fixation duration. The analysis of fixed effects only showed a statistically significant session effect in the 2v2 scenario ($p = 0.04$, ES = 0.61 ± 0.56), while the analysis of least square means differences did not show a statistically significant group or session effect. Both groups increased the fixation duration pre to post in the 2v2 scenario.

Fixation order. The analysis of fixed effects showed a statistically significant session effect in all conditions ($p < 0.01$); a statistically significant group x session effect in the early scenario ($p = 0.04$) and a group x session effect in overall ($p = 0.08$); no statistically significant group effect in any condition. The analysis of least square means showed small statistically significant session effects in all conditions in FUT, overall ($p < 0.01$, ES = 0.33 ± 0.18), 2v2 ($p < 0.01$, ES = 0.41 ± 0.27), 4v4 ($p < 0.01$, ES = 0.27 ± 0.18), early ($p < 0.01$, ES = 0.36 ± 0.20), and late ($p < 0.01$, ES = 0.29 ± 0.19), while there were no statistically significant session effects in SOC. FUT increased the number of ball-other locations fixation alternations from pre to post.

Relative viewing time. The analysis of fixed effects showed a statistically significant session effect in ball (p = 0.01); a statistically significant group x session effect in teammate-opponent pair (p = 0.04) and a group x session effect in non-marking opponent (p = 0.09). The analysis of least square means difference showed a statistically significant session effect in FUT in the ball (p = 0.02, ES = 1.16 ± 0.94); moderate session effects in FUT in teammate-opponent pair (p = 0.09, ES = 0.67 ± 0.79) and in non-marking opponent (p = 0.06, ES = 0.91 ± 0.94) (figure 3). FUT decreased the time spent fixating teammate-opponent pairs and increased the time spent fixating ball and non-marking opponent. Furthermore, there was a moderate group effect in the post-test (p = 0.12, ES = 0.99 ± 1.31) in free teammate. FUT spent more time fixating free teammate than SOC (figure 3).

******Figure 3 near here******

Dual-task performance

The analysis of fixed effects showed a statistically significant session effect in single-task (p = 0.02) and dual-task kick performance (p < 0.01), while there was no statistically significant effect in dual-task cost. There were no statistically significant group or group by session effects in any of the dual-task conditions. There was a statistically significant improvement in the single-task and dual-task kick performance throughout the study in both groups. The analysis of least square means showed a statistically significant improvement in dual-task kick performance from session 1 to post-test in FUT (p = 0.02, ES = 1.08 ± 0.88) and in SOC (p < 0.01, ES = 1.14 ± 0.82). Both groups developed similar level of skill automaticity.

Percentage transfer

The percentage transfer, from FB to SB, was 16% and 29% in the overall and late condition, respectively.

Correlations

There were large correlations between gaze data (fixation duration and count) and performance accuracy in overall ($r = 0.51$, $p = 0.13$; $r = -0.50$, $p = 0.14$), 2v2 ($r = 0.60$, $p = 0.07$; $r = -0.59$, $p = 0.07$) and early condition ($r = 0.54$, $p = 0.11$; $r = -0.57$, $p = 0.08$) in FUT, while there were no statistically significant correlations in SOC. In FUT, increases in fixation duration and decreases in fixation counts were correlated with improvement in performance accuracy. There were large correlations between dual-task kick and performance accuracy in 4v4 ($r = 0.50$, $p = 0.14$) and late condition ($r = 0.58$, $p = 0.08$) in SOC, while there were no statistically significant correlations in FUT. In SOC, increase in dual-task kick error was correlated with improvement in performance accuracy.

Discussion

The aim of this study was to investigate the transfer of passing skill from a FB to a SB, and the perceptual skill underpinning the process. It was hypothesised that positive transfer of passing skill from FB to SB would be indicated by greater improvements in passing performance of FUT relative to SOC. The results confirmed this hypothesis as FUT showed higher pre- to post-test improvement (i.e., larger effect sizes) and higher post-test passing performance than SOC in all conditions, except the early condition. Practicing with a FB promoted a functional coupling of affordance perception and coordination patterns that, when adapted to a SB, improved performance. Particularly, the large between-group difference in performance in the late condition showed that FB fostered the development of participants' ability to functionally couple perception and action in a time-constrained situation, i.e., the teammate was free for a shorter period of time and participants had less time to organise the passing action.

The superior performance in FUT was hypothesised to be underpinned by development of an efficient perceptual attunement to task-relevant cues, i.e., higher fixation alternations between ball and other areas, lower fixation time on ball and higher fixation time on players. The results confirmed that higher passing improvement in FUT was underpinned by significant changes in their gaze behaviour, while SOC only slightly modified their perceptual skill. Despite minimal changes in fixation duration and count in both groups, the results of relative viewing time and fixation order indicated that changes in perceptual attunement started to appear in FUT but not in SOC. The changes in gaze behaviour in FUT partially confirmed the hypothesis as they increased the number of fixation alternations between the ball and other areas (i.e., fixation order). FUT also increased the fixation time on ball (contrary to predictions), increased fixation time on non-marking opponent, and decreased fixation time on teammate-opponent pairs. Changes in both groups' viewing time resulted in FUT fixating free-teammates for longer than SOC. In addition, changes in fixation duration and count were correlated with passing improvements in FUT but not in SOC. Despite not entirely confirming the hypothesis, the perceptual modifications coupled with a larger improvement in FUT, indicate that FB facilitated the development of an efficient perceptual attunement to task-relevant cues that supported passing performance.

It was hypothesised that changes in perceptual skill would be promoted by higher skill automaticity in FUT. The results did not confirm this hypothesis as both groups showed similar improvement in skill automaticity throughout the intervention. Despite being easier to kick (Peacock et al., 2017), the FB did not fast-track the development of skill automaticity compared to SB. These results seem to contradict previous research that showed that easy-to-handle equipment places fewer attentional demands on performer, in turn, facilitating skill automaticity (Buszard et al., 2014). However, a higher skill automaticity in FUT might have been masked by the design of the dual-task assessment. Both dual-task kicking and counting cost did not improve throughout the study in both groups suggesting that, potentially, counting backwards and kicking did not challenge participants' allocation of attention. Participants perhaps focused their attention on counting when the ball was rolling towards them and then switched attentional focus on kicking once the ball was close to them. Therefore, participants' attention was slightly affected during the kicking action, and skill automaticity was not evaluated properly in the two groups. Therefore, the changes in perceptual skill in FUT might have actually been promoted by participants' skill automaticity that was not captured with the adopted dual-task assessment. A potential research direction stemming from these results would be to use a probe dual-task (Abernethy, 1988; Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007), where participants respond to a secondary task during the execution of the pass, instead of a continuous dual-task, as adopted in this study.

Mechanisms other than skill automaticity might have encouraged the development of the observed behaviours. Previous research highlighted that equipment scaled to the participants' characteristics facilitated the execution of a skill, skill accuracy and encouraged more opportunities to execute a skill (Buszard et al., 2016b). This suggests that modified equipment might reduce movement variability, which would explain skill accuracy and easiness in executing a skill, and, in turn, might promote the repetitions of a small number of movement solutions, which was suggested to fast-tack the development of functional coordination patterns (Ranganathan & Newell, 2013). In addition, haptic information changes when properties of equipment are modified, and these changes in information likely play a role in the learning process. Kicking a futsal or a soccer ball provides different haptic information to the person performing the kick due to differences in the balls' coefficient of restitution. While previous research focused on visual information, haptic information has been argued to be important for coordinated movement as much as, if not more, than vision (Turvey, Burton, Amazeen, Butwill, & Carello, 1998), and an enhanced sensitivity to haptic information has been suggested to fast-track learning (Davids, Button, & Bennett, 2008a). Therefore, a futsal ball might have reduced movement variability and/or improved participants' sensitivity to ball touch during practice, and, in turn, encouraged the development of the observed gaze behaviour. A potential future direction would be to assess movement variability and participants' sensitivity to haptic information when equipment is modified.

Previous research showed that futsal task constraints, including the ball, influenced the orientation of attention underpinning passing, i.e., higher attention alternations between ball and other areas, and lower attention time on ball relative to soccer task constraints (Oppici et al., 2017). These results were partially confirmed in the current study as FUT showed higher alternations between ball and other locations than SOC but FUT also increased fixation time on ball. However, participants in Oppici et al. (2017) were skilled junior players, while participants in this study were novices and the different skill levels might have influenced attentional focus on ball. It is possible that individuals' perceptual attunement to the FB, as a source of information, follow an inverted-U-shape along the expertise continuum. Typically, novices mainly rely on visual information to guide action but as they progress through the expertise continuum they increasingly learn to use haptic information (e.g., foot-ball contact) (Misceo & Plankinton, 2009). In this context, FB might promote the use of haptic information over visual information on ball only in experts, who are able to exploit FB properties (e.g., regular ball bounce and trajectory), being at the skill level (Handford, Davids, Bennett, & Button, 1997). Future research direction would be to evaluate the influence of modified equipment on individuals' ability to use haptic information to guide action and how the learning process is affected. An individual's level of expertise likely influences how equipment modification shapes skill learning and transfer. Therefore, future research could examine how equipment modification shapes the behaviour of individuals at different expertise levels.

A constraints-led approach, where constraint modification guides learning, as opposed to the traditional coach-led approach, where the coach guides learning, has been suggested to facilitate functional movement adaptations (Davids et al., 2008b). Task constraints, including equipment, have been the focus of this approach as they can be readily manipulated by practitioners. For example, sport programs, such as Tennis Australia's Hot Shots program, have recently started to scale equipment and playing area to the children's physical characteristics to encourage their engagement, enjoyment and development of sport skills (Tennis Australia, 2018). The results of this study provide new insights supporting this approach. Although constraints- and coach-led approaches were not compared, this study showed that practicing the passing skill with the same instructions but with a different ball influenced the learning process. Practicing the passing skill with FB was more beneficial than SB in improving passing skill with SB, as previous research (Travassos et al., 2017) and anecdotes suggested (UEFA, 2014). Practitioners working in soccer are encouraged to use FB in their training sessions to fast-track learning, particularly in novices.

Despite coupling the perception of information specifying affordances and the kicking action, the representativeness of the passing task adopted in this study could be improved in future research. Rather than projecting players on a video screen and kicking to a target placed at a fixed distance, the passing task could be performed with live players moving to receive the pass. The ecological validity of the task would improve, and participants would perform passes to players positioned at different distances in each pass. Therefore, they would need to appropriately change the speed of their pass to accurately reach the intended teammate. Furthermore, future research could examine the transfer of passing skill using a soccer game as transfer task, and improve the generalisation of the findings to the game.

This study investigated issues that were relatively un-explored in the human movement field providing results that extend the current understanding of the impact of modified equipment on skill learning. The results showed that practicing a passing skill with a modified ball promoted positive transfer to performing passes with another ball. The participants that practiced with the futsal ball showed greater improvement in passing accuracy than participants who practiced with the soccer ball. Furthermore, the results showed that the equipment participants trained with influenced the perceptual attunement to environmental cues. Practicing passes with the futsal promoted the education of attention towards information specifying affordances, i.e., teammate-opponent relationships. In summary, this study confirmed that modified equipment influences the self-organisation of perception-action coupling, which, in turn, shapes the development of a behavioural repertoire that can positively transfer to another equipment improving learning of a perceptual-motor skill (Araújo et al., 2004; Farrow et al., 2016).

Acknowledgments

The authors would like to thank all participants for their important contribution to this study.

Conflicts of Interest and Source of Funding

No funding sources were used in this study and the authors declare that they have no conflict of interest relevant to the content of this study.

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Table 1 Characteristic data (mean ± SD) for the two groups in relation to age and sport participation experience.

	FUT	**SOC**	**p value**
Age	24.6 ± 4.2	23.5 ± 5.5	0.59
Soccer experience (hours)	115.8 ± 119.5	124.8 ± 96.5	0.84
Team-sport experience (hours)	100.8 ± 89.9	97.5 ± 94	0.93
Pre-test performance accuracy (AU)	0.10 ± 0.03	0.09 ± 0.05	0.92

Table 2 Analysis of least square means differences in performance accuracy of FUT (i.e., group that trained with futsal ball) and SOC (i.e., group that trained with soccer ball).

	Pre-to-post Within-group differences		**Between-group differences**	
Scenario	**FUT**	**SOC**	**Pre-test FUT/SOC**	**Post-test FUT/SOC**
Overall	$p < 0.01$ (2.06 ± 0.86)	$p = 0.02$ (1.03 ± 0.82)	$p = 0.95$ (0.03 ± 1.10)	$p = 0.06$ (1.07 ± 1.10)
2v2	$p < 0.01$ (1.71 ± 0.86)	$p < 0.01$ (1.21 ± 0.83)	$p = 0.71$ (0.18 ± 1.00)	$p = 0.16$ (0.69 ± 1.00)
4v4	$p < 0.01$ (1.34 ± 0.87)	$p = 0.10$ (0.70 ± 0.84)	$p = 0.78$ (-0.14 ± 1.01)	$p = 0.32$ (0.50 ± 1.01)
Early	$p = 0.03$ (0.96 ± 0.86)	$p = 0.02$ (1.03 ± 0.83)	$p = 0.81$ (0.12 ± 1.00)	$p = 0.93$ (0.04 ± 1.00)
Late	$p < 0.01$ (2.61 ± 0.87)	$p = 0.07$ (0.76 ± 0.83)	$p = 0.97$ (-0.02 ± 1.07)	$p < 0.01$ (1.83 ± 1.07)

Pre-to-post within-group differences and between-group differences at pre-test and post-test are presented as p value (effect size ± confidence limits). Significance was set at $p < 0.05$.