# Relationship between constant and variable practice and kinematic characteristics of the basketball free-throw


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Dissertation submitted in fulfilment of the requirements for the degree Master of Health Sciences in Human Movement Sciences at the North-West University

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## PREFACE

“For this life we know will soon be passed, only that done for Christ will last” – Mike Fluech.

By this saying I wish to dedicate this dissertation to Jesus Christ, without Whom this would not at all have been possible, and it is because of Him that I get to stand here and say thank you.

Thank you to the strength you gave me to keep on working, to hold on through the last couple of years where giving up was a much easier route, but still allowed me hope to finish what I took on back in 2016.

With great appreciation and love, I would like to thank my wife – Emmari Pretorius. Without you, I would have given up on the hope of finishing this climb a long time ago, when negativity became second nature, when you gave me new meaning of positivity and what was possible if you realized where your strength came from. Your love and support is of utmost and unbelievable importance and value to me!

To my parents, without whom the last 8 years of studies would not have been possible – every little bit of support emotionally and of course financially, every strong word and every single motivating word. Your love is something I strive to have someday for my children, family and aspire to care and love for them as you do for me. To my sister, who is the true example of Godly love, no matter the colour or culture of a person – whose heart is that of someone wanting more of God and being more and more like Him.

Lastly, to my study leaders: If anyone has had it harder than me in my dissertation, it is them. They had had to sit up with immense patience during the times when I had no work done when they spoke and tried to teach, but I did not listen nor wish to learn. They motivated throughout; they kept believing it was possible for me to finish, and after 3 years, they are crossing the finish line with me! Thanks Stan and Adele, I will forever be grateful for the role you played in furthering my career, and the things you taught me about research and life.

**DECLARATION**

The co-authors of the two articles which form part of this dissertation (NWU-00117-17-A1), Dr S.H. Czyz (supervisor) and Dr A. Broodryk (co-supervisor) hereby give permission to the candidate Mr Elric Pretorius to include the two articles as part of his master's dissertation. The contribution (i.e. supportive and advisory) of the co-authors was kept within limits of reason and in this regard allowed the student to submit this dissertation for May / June 2019 examination, in order to qualify for the October graduation ceremony.

Furthermore, this dissertation, therefore, serves as partial fulfilment of the requirements for the Magister Arts degree in Sports Science within PhASRec (Physical Activity in Sport and Recreation – Faculty of Health Sciences) at the North-West University, Potchefstroom Campus, and South-Africa.

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**ABSTRACT**

This affiliated study is subject to the original objectives and study design of the project "*Gaze behaviour and kinematics of especial skills*". The assessment and analysis of movements or parts of movements through kinematics has become a useful "tool" in movement analysis, where researchers believed that kinematics had recently become an important descriptor of performance in motor learning and control. The objectives of this study were to determine the differences and effect sizes of the differences in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between the basketball free throws (4.57 m) practised in constant and variable conditions. These kinematical differences and their effect sizes were observed on testing days and after intervention training days. The differences in shot proficiency from the free throw distance (4.57 m), were also observed to see the relevant effects that the applied intervention programme had relevant to, and within, constant and variable practice conditions groups.

A five-day programme was conducted of which day one consisted of a pre-test, day two to four the intervention training days and day five a retention-test. Twenty (N=20) fit and healthy male participants (age 21.8 ± 1.8 years) were randomly divided into constant (n=10) and variable (n=10) practice groups. Informed consent was granted by participants, with the option to withdraw at any time. Each participant shot 20 free throws from five different distances (3.35 m, 3.96 m, 4.57 m, 5.18 m and 5.79 m – 20 shots per distance) resulting into 100 shots per day. During the three-day training programme, the constant group remained with 100 shots from the 4.57 m line, while the variable group shot 20 shots from each of the five distances. Participants were required to wear sleeveless shirts or no shirts to enable proper upper body analysis, whereas short trousers allowed adequate analysis of the lower body. For consistency, players had to be barefoot to allow an appropriate view of the ankle and foot. Nine reflective markers were used for analysis and put on the dominant side of the participant at the following locations: distal end of the fifth metatarsal of the toe, lateral malleolus of the ankle, lateral condyle of the femur and the greater trochanter of the femur. A further five landmarks were used on the upper extremity: distal end of the middle finger just below the nail, the hand about 1 cm below the middle finger, ulnar styloid of the wrist, lateral epicondyle of the elbow and the acromion process of the shoulder. Five different landmarks were attached within each recording, namely negative peak velocity (A), peak flexion (B), peak acceleration (C), peak velocity (D) and negative peak acceleration (E). Linear regression was computed for all the distances (except the free throw distance), for each participant and, based on the individual regressions, the predicted values at the free throw distance (4.57 m).

The biggest difference between the constant- and variable groups in the pre-test was observed in landmark B (peak flexion). The variable group attained the highest value of the two groups, while in the post-test the biggest difference between the two groups was observed in landmark E (negative peak acceleration), this time with the constant group having the higher relative timing percentage. Since only one main effect was significant and the interaction was not, no additional posthoc analyses were performed. In relation to the objective, it is observed that the biggest difference between the predicted performance and the actual performance was at the 4.57 m free throw distance. This was the case in both the pre-test and retention-test of the constant group. However, the greatest difference was only noticed in the pre-test of the variable group, not in its retention-test.

**Keywords**: *kinematics, basketball free throw, especial skill, variability of practice, specificity of practice, shot proficiency*

# OPSOMMING

Hierdie geaffilieerde studie is onderworpe aan die oorspronklike doelstellings en studieontwerp van die projek "*Gaze behaviour and kinematics of special skills*". Die assessering en analise van bewegings of dele van bewegings deur kinematika het 'n nuttige "instrument" in bewegingsontleding geword, waar navorsers geglo het dat kinematika onlangs 'n belangrike beskrywing van prestasie in motoriese leer en beheer geword het. Die doelwitte van hierdie studie is om die verskille en effekgroottes van hierdie verskille in kinematiese gedragspatrone en kinematiese parameters te bepaal (dit wil sê pieke in fleksie, hoeksnelheid en hoekversnelling) tussen die basketbal vry-gooie (4.57 m) wat in konstante- en veranderlike toestande beoefen word, op toets-dae en na-intervensie opleidingsdae, en verskille en hul effekgroottes in doelvaardigheid van die vrygooi-afstand (4.57 m) as gevolg van 'n toegepaste intervensieprogram, tussen en binne veranderlike en konstante praktykgroepe.

‘n Vyfdagprogram is uitgevoer, waarvan die eerste dag se program bestaan het uit 'n voortoets, dag twee tot vier, die tussenkoms opleidingsdae en dag vyf 'n retensietoets. Twintig (N=20) geskikte en gesonde manlike deelnemers (ouderdom 21.8 ± 1.8 jaar) is lukraak verdeel in konstante (n=10) en veranderlike (n=10) oefengroepe. Ingeligte toestemming is deur die deelnemers toegestaan, met die opsie om ter enige te onttrek. Elke deelnemer het 20 vrygooie vanaf vyf verskillende afstande gegooi (3,35 m, 3,96 m, 4,57 m, 5,18 m en 5,79 m - 20 skote per afstand) wat tot 100 skote per dag gelei het. Tydens die driedaagse opleidingsprogram het die konstante groep gehou by 100 skote van die 4.57 m-lyn, terwyl die veranderlike groep 20 skote van elk van die vyf afstande gegooi het. Deelnemers was verplig om moulose hemde of geen hemde te dra om behoorlike bolyf-analise moontlik te maak, terwyl kort broeke die doeltreffende ontleding van die onderlyf toegelaat het. Vir konsekwentheid moes deelnemers kaalvoet wees om 'n behoorlike beskouing van die enkel en voet toe te laat.

Nege reflektiewe merkers is vir die doel van analise gebruik en op die dominante kant van die deelnemer op die volgende plekke geplaas: distale einde van die vyfde metatarsale van die tone, laterale malleolus van die enkel, laterale kondiele van die femur en die groter trochanter van die femur. ‘n Verdere vyf landmerke is op die boonste ledemaat gebruik: distale einde van die middelvinger net onder die nael, die hand ongeveer 1 cm onder die middelvinger, ulnêre stiloïed handgewrig, laterale epikondiel van die elmboog en die akromioniese proses van die skouer. Vyf verskillende landmerke binne elke opname was aangedui, naamlik negatiewe pieksnelheid (A), piekbuiging (B), piekversnelling (C), spitsnelheid (D) en negatiewe piekversnelling (E). ‘n Liniêre regressie is bereken vir alle afstande (behalwe die vry-gooi afstand), vir elke deelnemer

en op grond van die individuele regressies het ons die voorspelde waardes bereken vir die vry-gooi afstand (4.57 m). Die grootste verskil tussen die konstante en veranderlike groepe in die voortoets is waargeneem in landmerk B (piekbuiging), met die veranderlike groep wat die hoogste waarde van die twee groepe behaal het, terwyl die na-toets die grootste verskil tussen die twee groepe in landmerk E (negatiewe piekversnelling) waargeneem is, hierdie keer met die konstante groep wat die hoër relatiewe tydspersentasie het. Aangesien slegs een hoof-effek betekenisvol was en die interaksie nie was nie, is geen addisionele post-hoc ontledings uitgevoer nie. Met betrekking tot die doelwit is opgemerk dat die grootste verskil tussen die voorspelde prestasie en die werklike prestasie op die 4.57 m vry gooi afstand was. Dit was die geval in beide die voortoets en retensietoets van die konstante groep. Die grootste verskil is egter eers in die voortoets van die veranderlike groep opgemerk, nie in die retentietoets nie.

**Sleutel woorde***: kinematika, basketbal vrygooi, spesiale vaardigheid, veranderlikheid van praktyk, spesifisiteit van die praktyk, doelvaardigheid*

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[1] Headings not numbered to correspond with article guidelines

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| *d* | Cohen's effect size |
| eGMP | Especial Generalised Motor Programme |
| FIBA | International Basketball Federation |
| Ft. | Feet |
| GMP | Generalised Motor Programme |
| Hz | Hertz |
| i.e. | In example |
| NBA | National Basketball Association |
| NFL | National Football League |
| NWU | North-West University |
| p | Statistical significance |
| $R^2$ | Effect Size |
| SD | Standard Deviation |
| y | years |
| º/s | Peak velocity |
| -º/s | Negative peak velocity |
| $º/s^2$ | Peak acceleration |
| $-º/s^2$ | Negative peak acceleration |

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

The basketball shot is a crucial element in the sport of basketball, as the winner of the game will be the team that scored most points *(i.e. successful shots*) at the end of a match (International Basketball Federation (FIBA), 2014:5; Struzik *et al*., 2014:216). Struzik and co-workers (2014:216) stated that regardless of the shooting technique used, its accuracy rate should be the primary objective. With basketball, logically stated, accuracy and the improvement thereof are thus of critical importance (Struzik *et al*., 2014:216). Research emphasises the importance of acknowledging that basketball shots are taken from various distances and positions (Struzik *et al*., 2014:216).

One of the crucial shots known in basketball is the free throw (FIBA, 2014:6). A free throw is a shot directed at the opponent's basket, and if successful, would count 1 point for the attacking team (FIBA, 2014:19–20; National Basketball Association (NBA), 2014:18). This specific shot is taken from behind the free throw/foul line at the 4.57 m mark on the court (FIBA, 2014:17; NBA 2014, pp. 8-18) and must be taken within ten seconds since possession of the ball and a signal by the match official marking the start of the allowed time.

However, since the free throw is taken from only one distance (4.57 m), and not from various distances, players are not expected to practise these free throw shots from other positions on the court (Keetch *et al*., 2005:975). The importance of practice specificity in sport was recently emphasised by Czyz and Moss (2016:9) in their study on the emergence of an especial skill in archery, when they deemed the importance of practice of a specific skill to be a crucial factor in the emergence of 'advantages' over other skills. This was furthermore reiterated by Nabavinik *et al.* (2017:1) who found that in experienced archers the practiced shot had some sort of special advantage over other distanced shots. Hence the element *variable practice* must always be deemed important, as the factors needed to succeed may differ from one another (Struzik *et al*., 2014:216). Variable practice is described as *'practising with multiple variations of a specific movement task'*, and is believed to promote transfer to certain untrained movements owing to a general memory schema within one class of movements (Breslin *et al*., 2012a:154).

Because the free throw is taken from one specific distance, participants aggregate massive amounts of practice at this distance (Keetch *et al*., 2005:975; Breslin *et al*., 2010:56). This type of practice, i.e. practice of only one variation of a specific skill, which is repetitive and persistent, is called constant practice *(i.e. second independent variable)* (Breslin *et al*., 2012a:154). The effect of massive amounts of practice on shot proficiency was originally examined in eight male university students (age: 18–22 years) in a study done on the basketball free throw (Keetch *et al*., 2005:975). Keetch and colleagues (2005:975) compared the shot proficiency from distances other than the free throw line with the shot proficiency from the free throw line itself, pertaining to the question of '*massive amounts of constant practice on a specific skill*'. This finding was supported in more recent studies regarding different sport skills and specific training of these skills (Keetch *et al*., 2008:727; Simons *et al*., 2009:477; Breslin *et al*., 2010:55; Breslin *et al*., 2012a:154).

The results of their research (Keetch *et al*., 2005:972) stated that with an increase in throwing distance (2.74 m to 6.4 m), the accuracy of the shot decreased ($p < 0.05$). Some of the distances other than the free throw line were not significant enough ($p > 0.05$) to suggest that the advantage participants had at the free throw line was present at any of the other distances (Keetch *et al*., 2005:972). Based on the force variability principle, the researchers assumed a linear decrease in performance as the distance increased ($p < 0.05$) (Keetch *et al*., 2005:971).
The study by Keetch and colleagues (2005:972) on the basketball free throw reported an unexpected result from the 4.57 m mark. Keetch *et al*. (2005:976) found that the accuracy rate was in accordance with that of the closer distances to the basket ($p < 0.05$), i.e. the shot proficiency at the free throw distance was much higher than could be expected, based on the force variability principle. Their results support the emergence of a 'specific advantage' for a highly practised free throw shot in the more general class of basketball shots (Keetch *et al*., 2005:972; Keetch *et al*., 2008:727). These findings are similar to those in other studies regarding baseball (Simons *et al*., 2009:477), basketball (Breslin *et al*., 2010:56; Breslin *et al*., 2012a:155) and archery (Nabavinik *et al*., 2017:1). This, however, was not found by Cañal-Bruland *et al*. (2015:548), who reported no occurrence of the 'specific advantage' at the free throw line as found by the above-mentioned studies, with no significant difference ($p = 0.8$) between the free throw line success and success at other distances.

Original analysis of the *'unique skill'* from the basketball experiment of Keetch *et al*. (2005:976), in particular the 'outperformed shot proficiency' from the 4.57 m line, was described by the term *'especial skill'*, and can be defined as 'a highly specific skill embedded within a more general class of motor skills' (Keetch *et al*., 2005:976; Czyz *et al*., 2013:139). This skill can be attributed to accumulated training from the foul line to take set-shots (Keetch *et al*., 2005:976; Keetch *et al*., 2008:727). According to research on basketball and baseball, the uniqueness of an especial skill was credited to the large amounts of practice with regard to the highly specific skill ($p$ < 0.05 and $p$ < 0.01) (Keetch *et al*., 2005:976; Simons *et al*., 2009:477). This was further supported by recent studies (Breslin *et al*., 2010:56; Breslin *et al*., 2012a:155; Carson & Collins, 2016:7; Czyz *et al*., 2013:149; Nabavinik *et al*., 2017:1). Carson and Collins (2016:7) further emphasized that even though massive amounts of practice seamed plausible as an explanation for especial skill emergence, superior motor control and functioning could have an effect, but that research was still in too an early stage to definitely make a conclusion on what causes the uniqueness of the skill.

The study on basketball (Keetch *et al*., 2005:976) and baseball (Simons *et al*., 2009:477) manipulated the distance from which the participants had to shoot and pitch, with a view to investigate whether participants showed the emergence of an 'especial skill' as a result of massive amounts of practice. Practice from only the 4.57 m distance provided an advantage over other distances in the free throw, as described in the experiment above; and significant linear regression ($p$ < 0.05) was expected with this experiment when considering all the distances – the free throw distance excluded (Keetch *et al*., 2005:976). However, when Keetch *et al*. (2005:976) compared the results with the predicted outcome, they found a significant difference in the actual performance compared to the predicted outcome at the free throw line ($p$ < 0.05) (Keetch *et al*., 2005:976). Similar effects were seen in baseball pitchers when the ball was thrown from the fixed pitching distance of 60.5 ft./18.44 m ($p$ < 0.018), demonstrating a predicted especial skill (Simons *et al*., 2009:477), and in similar studies on basketball free throws (Breslin *et al*., 2010:56; Breslin *et al*., 2012a:154; Stöckel & Breslin, 2013:539), which all showed successful representation of the especial skill.

The studies by Keetch *et al*. (2005:976) and Simons *et al*. (2009:477) attributed their outcome to the presence of predicted *'especial skills'*. However, other studies (Keetch *et al*., 2008:729; Stöckel & Breslin, 2013:539) showed that participants used constant visual-context information to adapt to the manipulated or irregular shooting (Keetch *et al*., 2005:976) and pitching distances (Simons *et al*., 2009:477) in addition to the practice accumulation. The results of Stöckel and Breslin's experiment (2013:539), in which they manipulated the basketball rim 30 cm closer to and further from its original position, were in contrast with the research findings of Keetch *et al*. (2005:976) and Simons *et al*. (2009:477). Although it presented evidence of an especial skill, in these two above-mentioned experimental studies (Keetch *et al*., 2005:976; Simons *et al*., 2009:477), natural sport-like situations were manipulated, forcing participants to use visual-context information incidentally, not that normally available in their respective sports (Keetch *et al.*, 2008:727; Stöckel & Breslin, 2013:539). The creation of these 'incidental cues' obviated their visual-contextual influence on their motor-skill specificity (Keetch *et al.*, 2008:727; Stöckel & Breslin, 2013:539). Their findings (Keetch *et al.*, 2008:727; Stöckel & Breslin, 2013:539) were supported by a more recent study conducted by Cañal-Bruland *et al.* (2015:553), in which they attempted to determine whether basketball players with the free throw 'especial skill' would be able to predict the success of their shots from other distances. However, their results showed no presence of the so-called especial skill at the foul line, eliminating its entire existence (Cañal-Bruland *et al.*, 2015:553). In fact, a low percentage of successful shots overall was recorded, and no significant difference ($p$ = 0.787) was observed between the free throw distance and other adjacent distances (Cañal-Bruland *et al.*, 2015:553).

### 1.2 Problem statement

Previous research has not proven whether the appearance of the especial skill resulted from the amount of practice in the skill (Keetch *et al.*, 2005:976) or whether it in fact resulted from the type of practice specificity *(constant and variable practice*), regardless of time spent on practising or mastering the skill (Breslin *et al.*, 2012a:154). Practice specificity and its effect was tested by Breslin *et al*. (2012a:154) by manipulating the type of practice to test whether the especial skill does indeed emerge as a result of the constant or repetitive practice (practice at the 15 ft. line only) regime. As predicted, both groups (constant vs. variable practice groups) improved their basketball shot accuracy from the 4.57 m (free throw) line, with no significant difference between the two groups ($p$ < 0.18) (Breslin *et al.*, 2012a:155). Thus, the difference between the constant or variable practice group was not significant enough to suggest that constant practice favours especial skill emergence above that of variable practice (Breslin *et al.*, 2012a:155). These findings are in contrast with previous research (Keetch *et al.*, 2005:976; Simons *et al.*, 2009:477) suggesting that massive amounts of practice are needed for the emergence of an especial skill. In addition, a mere 300 practice trials were needed to evoke an execution pattern for the specific skill regardless of the amount of time spent during training (Breslin *et al.*, 2012a:156). This finding (Breslin *et al*., 2012a:156) was in line with the theory of specificity in motor learning, originally discussed by Adams (1987:59) in an early study on human motor skills. Adams (1987:59) found that when a new movement was acquired, a perceptual representation of that movement was formed, each one governed by its own memory representation, and Breslin *et al*. (2012a:156) supported this theory. However, this was in direct contrast to the findings of an even earlier study on memory representation, known as the 'schema theory' (Schmidt, 1975:232).

Based on the schema theory, Breslin *et al*. (2012a:154) claimed that variability in practice will promote transfer to other, untrained movements in the same class of action because of a 'memory schema', supported by Breslin *et al*.'s (2010:56) earlier research. Thus variable training in the free throw shot will possibly have a positive effect on the shot proficiency of other types of basketball shots. Schmidt's (1975:232) theory on memory schemas created a notion stating that there was a generalised motor programme (GMP) for a specific class of movement, i.e. the many ways of throwing a baseball during a match. Similarly, Simons and his co-workers (2009:470) also supported the theory, stating that the schema provided for generality and skill transfer, especially in the same class of movement (i.e. baseball pitching/throwing; basketball shots etc.). Recent research on the emergence of an especial skill in archery (Czyz & Moss, 2016:10) provided results that were in line with the theory of Schmidt (1975:232), referring to generalisability in motor learning, i.e. the schema theory.

A further analysis of GMPs involved in skills such as the basketball free throw, among other shots (Keetch *et al*., 2005:1972), shed light on three key principles identified as crucial in distinguishing between different skills (Schmidt *et al*., 1975:235). These three factors were identified as relative force of execution, relative timing of execution, and the sequence order in which the different steps in the skill are performed (Schmidt *et al*., 1975:235). Keetch *et al*. (2005) suggested that a massive amount of constant practice may lead to the development of especial GMPs that can eventually execute and govern especial skills. This hypothesis was repudiated by Breslin *et al*. (2012a:155), who used biomechanical analysis, and more specifically kinematic analysis; *"a detailed studying of a movement sequence, usually that of a human, one could use kinetics (force etc.) and kinematics (angles etc.) as a tool, or a means to an end, in determining certain questions"*. This analysis involved certain kinematic parameters on which Breslin *et al*. (2012a:155) focused, which were the original parameters used by Schneider and Schmidt (1995:34). Five distinct landmarks were used from each recording/analysis, which corresponded with peaks in flexion, angular velocity and angular acceleration (Schneider & Schmidt, 1995:34). These calculations were based on the elbow joint, as this joint showed most movement during the propulsion phase of the movement (Breslin *et al*., 2010:57). Breslin *et al*. (2012a:155) noticed a significant distance effect ($p$ = 0.01) regarding the accuracy of shots performed from the free throw distance and other distances, assuming that especial skills are governed by the same GMP as the rest of the movement from within the class of action.

Future studies regarding kinematic parameters are proposed, as these can assist in formulating a model that potentially defines, determines, and creates the way for especial performance (Fay *et* *al*., 2013:717). This was further emphasised by Breslin *et al*. (2010:56) when they suggested potential research platforms in kinematic analysis, such as the relative timing of the moving upper- and lower limbs during the free throw, something of special interest to the current research project. Furthermore, Fay *et al*.'s (2013:717) statement was supported when Schade (2010:28) deemed it crucial to use biomechanical analysis in coaching, forming part of important fundamentals needed for the development of an athlete's performance, and as a result shed light on the importance of other biomechanical research studies (Dobovicnik *et al*., 2015:11). Such biomechanical research included that of Dobovicnik and his fellow researchers (2015:11), in which they found release angles and entry angles in the basketball shot to be more important, focussing on the principle of biomechanical analysis and its use as a tool in researching *'especial skills'*.

It could be argued that constant practice builds a memory representation that differs from variable practice, and given that GMPs can be differentiated with regard to their kinematic behaviour (relative timing according to Schmidt's schema theory) (Schmidt, 1975:235), two detailed questions are posed:

1. What are the practical and statistically significant differences in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between constant- and variable practice participants in the execution of the free throw (4.57 m) in basketball on testing days and after intervention training days?
2. What is the practical- and statistically significant differences in shot proficiency from the free throw distance (4.57 m) as a result of an applied intervention programme, between and within variable- and constant practice groups?

Results will shed light on GMPs used in different skills, be these general or specific, but also on the effect of massive amounts of training and different kinds of training. This information will be beneficial to sport scientists, sport coaches and other sport professionals when attempting to optimise performance regarding specific and specialised sport skills. The information and data presented in this study, with specific reference to especial skills, will contribute significantly to sports where constant practice- or variable practice can also be experimented with; thus where distance, location etc. are definite parameters. As mentioned earlier in the current document, the definite variable of distance in sports, such as hockey or soccer penalty shots, basketball jump-shots and National Football League (NFL) field goals can benefit from the findings of this study.

## 1. 3 Objectives

The objectives of this study are to determine:

- the differences and its effect sizes in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between the basketball free throws (4.57 m) practiced in constant- and variable conditions, on testing days and after-intervention training days, and
- the differences and its effect sizes in shot proficiency from the free throw distance (4.57 m) as a result of an applied intervention programme, between and within variable- and constant practice conditions groups.

## 1.4 Hypotheses

As this is an exploratory study, it is difficult to predict outcomes. However, for the purposes of the proposal, the following is predicted:

- The constant-practice group will show a significant difference ($p < 0.05$) with a large effect size in kinematic parameters and kinematic behavioural patterns (i.e. peaks in flexion, angular velocity and angular acceleration) of the basketball free throw following the intervention session, as opposed to those in the variable practice group; and
- The constant practice condition group will demonstrate significantly better ($p < 0.05$) shot proficiency with a large effect size compared to the variable practice condition group for the free throw distance (4.57 m) as a result of an applied intervention programme.

## 1.5 Proposed Chapters

The dissertation will be submitted in article format as approved by North-West University and will be structured as set out below. Possible journals are included but articles will not necessarily be limited to these journals.

**Chapter 1**: **Introduction.** At the end of the chapter, a reference list will be provided in accordance with the guidelines of North-West University. This chapter includes the problem statement, the setting of objectives for our study, and our hypotheses based on the two objectives. It includes an indication of how the dissertation is prepared and what different aspects is focused on and discussed which forms the basis of our current study.

**Chapter 2**: **Literature review: Kinematic analysis and especial skills in constant and variable practice conditions in overhand throwing actions.** A reference list will be presented at the end of the chapter in accordance with the guidelines of North-West University.

**Chapter 3**: Article 1: **The different kinematic behavioural patterns of constant- and variable practice participants in the execution of the free throws (4.57 m) in basketball**

(This article will be submitted to the *Journal of Sport Sciences* according to their author guidelines , for possible publication – article, together with the references, are prepared according to the author guidelines of the respective journal – refer to Appendix D).

**Chapter 4**: Article 2: **Especial skill effect in constant practice conditions – study replication** (This article will be submitted to the *Journal of Motor Behaviour* for possible publication – article, together with the references, are prepared according to the author guidelines of the respective journal – refer to Appendix E).

**Chapter 5**: **Summary, conclusions, limitations and recommendations.**

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# CHAPTER 2

# LITERATURE REVIEW: KINEMATIC ANALYSIS AND ESPECIAL SKILLS IN CONSTANT AND VARIABLE PRACTICE CONDITIONS IN OVERHAND THROWING ACTIONS.

## 2.1 Introduction

Dobovicnik *et al*. (2015:5) recently stated that the modern game of basketball is dominated by quick, efficient shots aimed at the basket on the court. The shooting time, length and speed of shots are all factors taken into consideration when determining the success of shots, as these affect the game outcome (Dobovicnik *et al*., 2015:5). On the other hand, Struzik and co-authors (2014:216) state that irrespective of the shooting technique and type of shot taken (set-shot/foul shot/free throw, jump-shot etc.), the accuracy of the shot is the ultimate goal. Therefore, the accuracy and success rate of a basketball shot should be the primary objective of any team and/or player, regardless of the type of shot used (Struzik *et al*., 2014:216). According to the authors, making use of the players' kinematical analysis might increase the accuracy of the shot from various locations and distances (Struzik *et al*., 2014:217).

According to Dobovicnik *et al*. (2015:5), the most commonly used type of shot in the modern game of basketball is the jump-shot. A jump-shot refers to a shot taken while the player is airborne (Miller & Bartlett, 1993:287). On the other hand, the free throw is a set-shot, described as a movement involving both upper- and lower limb motion, while the feet are in contact with the floor (Keetch *et al*., 2008:727). It is taken from exactly the same position every time at the free throw line right below the basket, at a distance of 4.57 m (Keetch *et al*., 2008:727; FIBA, 2014:6; NBA, 2014:18). The player stands at the line, perpendicular to the backboard, with consistent visual surroundings (e.g. visual angles) throughout each free throw attempt (Breslin *et al*., 2012b:342). Due to the nature of basketball and the frequency of the free throw shot, it is considered important in basketball (Keetch *et al*., 2005:976). This then, can have an effect on the outcome of a game, hence resulting in a large amount of practice time spent on perfecting these free throws (Breslin *et al*., 2012b:337).

The free throw is not a shot used in regular-flow play, but is solely used for one specific facet in basketball, namely the foul- or set shot (Breslin *et al*., 2012b:337). However, as a result of its limited usefulness in regular/general gameplay, it is rarely trained from a distance other than 4.57 m, being the only shot in basketball that is taken from a single distance at the foul line (Keetch *et al*., 2005:975; Keetch *et al*., 2008:727). One main difference between the jump-shot

(Miller & Bartlett, 1993) and a free throw (Keetch *et al*., 2005; Breslin *et al*., 2012a; Breslin *et al*., 2012b) is the conditions under which it is practised. It is in the light of the above-mentioned shortcomings that this literature overview was completed.

The first aim of this literature overview was to give the reader a general understanding of basketball and more specifically, the importance of the free throw. Secondly, discussing the various practice conditions deemed vital, as it determines the process of autonomy and how various shots are taken in basketball. This was then followed with a thorough explanation of especial skills, together with all the relevant hypotheses in table format. After this, motor learning and programming were introduced to discuss the generality and specificity of practice in the development of a memory representation. Following this, biomechanical analysis was discussed, since it can contribute to the development of general motor programmes (GMP).

Because of the scarcity of literature on this specific domain, research studies dating back as far as 1971 were included to provide the reader with thorough understanding. Only studies that made use of adult populations (age: ≥ 18 years) as test subjects in overhead throwing sport codes, were included. Key words used during the searches included among others: biomechanics, basketball, free throw, generalised motor programming, practice conditions, especial skills. Computer searches were performed using the SportsDiscus and Academic Research databases. The Google Scholar internet search engines were also used to trace the available literature.
In the subsequent section the basketball free throw will be discussed in terms of how it is classified as a unique skill, and ultimately, an especial skill. This will be followed by various practice conditions, as well as the influence of biomechanics in GMP.

## 2.2 Basketball free throw: a unique skill

Keetch *et al.* (2005:972) contributed significantly to the first understanding of a unique shot – the basketball free throw. In their experiment, participants were asked to shoot a free throw shot from seven distances (ranging from 2.74 m; 3.35 m; 3.96 m; ***4.57 m***; 5.18 m; 5.79 m and 6.40 m), to test the performance from the official free throw distance of 4.57 m in comparison to the other six distances (Keetch *et al*., 2005:972). They assumed that the shot proficiency from the seven distances would follow a linear regression as earlier (Schmidt *et al*., 1978:195) confirmed (Keetch *et al*., 2005:972). This meant that they expected the shot proficiency to decrease as the distance from the basket increased (Keetch *et al*., 2005:972). However, a linear regression for all the distances except for the 4.57 m distance was found (Keetch *et al*., 2005:972).

In the experiments done by Schmidt *et al*. (1978:195), which focused on force production and variability, an average correlation of 0.95 for both experiments was reported, and when plotted, increased to 0.99. Schmidt *et al*. (1978:195) found these correlations to show a nearly linear relationship between the distances from where an aiming task was performed and the aiming accuracy. They argued that the change in force was proportional to the force variability, confirming their initial hypothesis that force and its variability were indeed proportional to the amount of force produced (Schmidt *et al*., 1978:195). Based on Schmidt *et al.'s* findings (1978) Keetch *et al*. (2005:972) computed a linear regression for the shot proficiency at all the other distances but the 4.57 m distance, and then calculated the proficiency for this free throw distance using the regression equation (Keetch *et al*., 2005:972). They then compared the predicted shot proficiency to the actual one from the test and found a significant difference (Keetch *et al*., 2005:972). The accuracy (i.e. proficiency) of the shots from this distance, compared to the other six distances, was significantly greater ($p < 0.05$) than predicted (see Figure 1).

Thereby, the negative linear relationship (i.e. distance from basket and success rate) was present for six of the seven distances, except for the free throw line (Keetch *et al*., 2005:972) and it was inconsistent with Schmidt *et al.* (1978) findings. Researchers ascribed this distinct difference to the massive amounts of accumulated training over time, since the location of the free throw is from a distance specifically trained at (Keetch *et al*., 2005:972; Keetch *et al*., 2008:727).

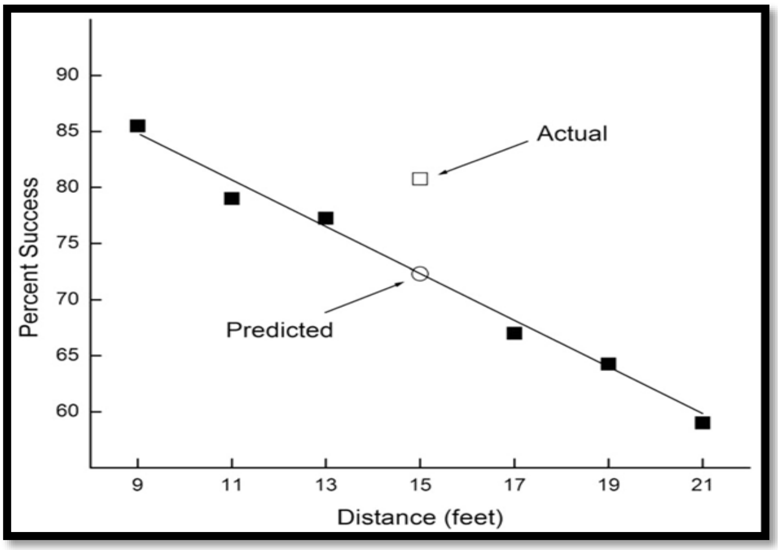


**Figure 2-1: Free throw performance from different distances**

*Results of Experiment 1 by Keetch et al. (2005:972): free throw performance in percentage (%) of success against the distance (ft.) at the foul line, and distances other than the foul line/free throw line. The filled squares represent the actual performance proficiency from the six other distances, while the clear square represents the actual performance from the 1 5ft. (4.57 m) free throw line. The clear circle on the regression line is the predicted performance proficiency from the free throw foul line (i.e. calculated on the basis of the individual regression of the* *other distances) (Keetch et al., 2005:972. Experiment 1 – Figure1: Set shot performance as a function of the distance from the basket).*

Subsequently, Keetch and colleagues (2005:973) did two other experiments, using the same distances as in Experiment 1, though using only five of the original seven distances (3.35 m; 3.96 m; ***4.57 m***; 5.18 m and 5.79 m). Experiments 2 and 3 replicated each other; several of the shots were taken while the distances were covered on the court (Experiment 3 used impaired visual aspects where players did not see the distance from where they shot to see if visual aspects played a significant role in shot proficiency - Keetch *et al*., 2005:973), while other shots were taken under normal conditions as in Experiment 1, but using other participants and a smaller ball (i.e. Experiment 2 – Keetch *et al*., 2005:973).

During Experiment 3 the jump-shot was used, as it is usually taken from different distances and angles on the court and included the variable of defenders always needing to be taken into account (Keetch *et al*., 2005:974). One of the most important differences between a set-shot and a jump-shot is the conditions under which they take place. A jump-shot has much more variability to consider (locations, defenders, angle from the basket) compared to the constant conditions (fixed angle and location) under which the free throw takes place (Keetch *et al*., 2005:974). The movements themselves could be seen as two entirely different classes of movements, with different practice conditions used to practise the two different shots – hence, set-shots were practised under constant conditions, whereas jump-shots were practised and mastered using variable practice conditions (Keetch *et al*., 2005:974).

## 2.3 Practice conditions

Previous research stated the importance of repeating actions to strengthen 'remembering' how to execute the movement (Magill, 1989:267). The term 'rote repetition' was used to refer to this type of repetitive rehearsal (Magill, 1989:267). Evidence up to that point suggested that this type of training resulted in fewer errors during execution (Magill, 1989:267). In addition, this type of training was more advantageous to closed skills (i.e. free throw), defined as a skill in which conditions surrounding the movement stayed constant and unchanged, as opposed to open skills, regarded as skills with unknown parameter conditions each time they are performed (i.e. jump-shot) (Magill, 1989:403).

Magill (2011:49) refers to a term called the 'general motor ability hypotheses'. This hypothesis states that all the different motor abilities that a person possesses are highly related and can be characterised according to a global motor ability (Magill, 2011:49). Hence, the notion suggests that a person who is skilled in one specific motor ability, will be able to become highly skilled in all his/her motor skills (i.e. transferability, as described on page 28) (Magill, 2011:50). This prediction, according to Magill (2011:50), is based on the grounds that there is one general motor ability in everybody, although very little evidence or research supports this. However, another hypothesis exists, which suggests that motor abilities are relatively independent, meaning that a person's ability to react very fast or rapid reaction time does not necessarily indicate that the person has very good hand-eye coordination (Magill, 2011:50). Since the free throw is a shot taken under the same conditions each time, players will never be expected to shoot under any other conditions than those under which they train. This type of practice is called '*constant practice*' (Keetch *et al*., 2005:975).

### 2.3.1 Constant- vs. variable practice

Magill (1989:421) also referred to constant practice as 'over-practice' or 'over-training'. This extra practice was deemed vital, as it was predicted that it would make the governing memory representation of that particular skill as accessible as possible (Magill, 1989:421; Magill, 2011:395). Lotfi and Rahmani (2015:863) used "overlearning" to describe this type of practice, a type of training they say should continue until it is internalized or a case of autonomy. They stated that the more a certain skill was trained in this way, the more stable it became (Lotfi & Rahmani, 2015:863). Furthermore, Carson and Collins (2016:5) also stated that with skill autonomy, the "steps" for retrieving a skill, or the execution thereof, are reduced and much easier accessible from long term memory.

In a statement regarding skill autonomy and overlearning, albeit much earlier, Magill (1989:421) reiterated that the main goal was to strengthen the relevant motor programme and response mechanism so that it could be retrieved and used at any time, hence defining this type as "*practice time spent beyond the amount of practice time needed to achieve some performance criterion*" (Carson & Collins, 2016:5; Lotfi & Rahmani, 2015:863; Magill, 1989:421; Magill, 2011:395). It has been seen as extra practice to further the retention and recall of a certain skill when used in performance (Lotfi & Rahmani, 2015:863; Magill, 2011:395). From such a perspective, Magill (2011:395) stated that one could understand how 'overlearning' has merit, both practically and on the basis of motor learning – the latter being in the sense that it would strengthen the governing motor programme of that motor skill, improving the response and recall mechanism through practising the particular skill. Retention has been an especial benefit of overlearning, according to Magill (2011:395) and other researchers (Lotfi & Rahmani, 2015:863).

Overlearning has shown benefits in different motor skills, according to Magill (2011:396); these are listed as procedural skills (i.e. skills performed in sequence with different steps), dynamic balance skills (i.e. maintaining control of the body while moving) and physical education skills (i.e. basic skills such as running and jumping, and more complicated skills requiring more co-ordination and control). Lotfi and Rahmani (2015:863) also reported the benefits of this type of training in both open– and closed skills (explained in depth on page 31). Very interesting though, Magill (2011:396) referred to a certain point in which overtraining reached a point of diminishing returns. This means that there comes a point where the extra training yields no more benefits, hence more training does not actually result in any further increase in performance than less training on that skill (i.e. it does not result in any more proportional retention performance) (Magill, 2011:396). This lack of retention benefits was especially relevant in dynamic balance skills; however, similar results have been seen in physical therapy and skills in a physical education class, as Magill (2011:396) noted.

Keetch *et al.* (2005:975) defined *constant practice* (specific) similarly as constant repetition and a massive amount of practice spent on mastering a single, specific skill during training, while in contrast, *variable practice* (generalised) referred to *'practicing multiple variations of a single movement task'* (Breslin *et al*., 2012a:154; Shoenfelt *et al*., 2002:1113). The benefits of constant practice can be linked to an even earlier theory of Thorndike (1914), namely the 'identical elements theory' (Magill, 1989:381; Magill, 2011:386). This theory stated that the similarities in fundamental components of two or more skills generated the level of transfer from one skill to another (Magill, 1989:381; Magill, 2011:386). Hence, the response was directly related to the type of stimulus and its similarities in response – the more similar the stimuli, the higher the transferability from one skill to another (Magill, 1989:381; Magill, 2011:386).

Accordingly, the more two skills had in common, the greater the transfer of characteristics from one skill to another would be during performance and learning (Magill, 2011:386). The *specificity of practice hypothesis*, traced all the way back to Thorndike (1914) and his identical elements theory, was hailed by Magill (2011:386) as possibly one of the oldest theories on human learning that is known and understood today. In short, Magill (2011:387) defined the *specificity of practice hypothesis* as "*the view that motor skill learning by practice condition characteristics, especially the sensory/perceptual information available, performance context characteristics, and cognitive processes involved.*"

Over time, this constant, persistent repetition of only one variation of a certain skill causes large amounts of practice accumulation in perfecting the skill (Keetch *et al*., 2005:975), which could also be seen as a reason why Shoenfelt *et al*. (2002:1113) stated that constant practice could result in a certain task becoming autonomous. This was supported more recently by Carson and Collins (2016:5), who stated that overlearning would help the autonomy of a skill, or at least parts of that skill, and in the process simplify memory retrieval.

To understand the process of a skill becoming autonomous, Figure 2 was adapted from Magill (1989:67), indicating the three stages to progress through as practice time increases. This figure describes the process of Fitts and Posner's model (1967), which was described by Magill (1989:67) later in his research. The key progression throughout the different stages is the number of errors that players are able to recognise and rectify themselves as they move nearer to autonomy – thus, their error response becomes greater over time (Carson & Collins, 2016:5; Lotfi & Rahmani, 2015:863; Magill, 1989:66). The cognitive phase of learning is characterized by slow and inconsistent movements. Practice sessions are more performance focused, less variable and incorporate a clear mental image. During the associative phase the movements become more reliable and efficient and less cognitive activity is required. Some parts of the movements are controlled consciously. The last phase is characterized by more accurate and consistent movements where very little to no cognitive activity is required. Movements is therefore controlled automatically and practice sessions are more results oriented. This is also the phase where focus is on greater range of motion, speed, acceleration, and use of skills (Oliveira & Goodman, 2004:315-324).


**Figure 2.2: Fitts and Posner (1967) three stage model of motor learning (Fitts P. & Posner. M. Human Performance).**

*As practice time increases, participant's progress through the phases until a skill/action becomes autonomous/automatic. This diagram is adapted from Magill (1989:67 – Figure 2.2.-1) who used and described the original model developed by Fitts and Posner (1967).*

The objective of Keetch *et al.'s* (2005:975) research regarding free throw especial skill was to test the performance from the distances mentioned (2.74 m; 3.35 m; 3.96 m; ***4.57 m***; 5.18 m;

5.79 m and 6.40 m) in comparison to the official distance (4.57 m), shedding light on another type of practice, '*variable practice'*. This in turn was defined by Shoenfelt *et al*. (2002:1113) as "*any practice that could lead players to generalise movements to conform to unfamiliar circumstances*", such as unfamiliar distances from which to shoot free throws. Shoenfelt *et al*.'s (2002:1113) findings showed better learning with variable practice compared to constant practice in their free-throw shot research. They tested the accuracy of the experimental groups from the free throw line after a three-week training programme (i.e. constant group from the free throw line, and the variable groups from other distances than the free throw line), with the results showing improvements in both groups (Shoenfelt *et al*., 2002:1113). However, when testing the retention of the different forms of practice, the variable training groups showed better retention than the constant group, who returned to their normal rate of success from the pre-test (i.e. before training) (Shoenfelt *et al*., 2002:1113).

Practice variability, and the experience thereof, increases the possibility of future performance success, Magill argued (2011:371). According to Magill (2011:371), previous successful motor control theories, such as that of Schmidt (1975), all focused on the benefits of practice variability, which refers to the variety of movement and context characteristics the learner experiences when he/she performs a skill. One main benefit that Magill (2011:371) emphasised regarding practice variability was the increased capability to perform a skill in the future under the conditions practiced, but also under novel conditions. Magill (2011:374) also referred to the relevance of variable practice in both closed- and open skills, where he found that with open skills, as it is in the nature of these skills, the constant variable or irregular/novel situations under which these skills are performed, are quite well suited to variable practice. Consequently, even open skills need to be practised in a variety of regular conditions and novelty situations, which constantly change (Magill, 2011:375).

Lotfi and Rahmani (2015:863) shed light on these two different types of skills during their research in overlearning, where they defined open skills as "*skills with an unstable environment which constantly change*", and closed skills those which are "*performed under a stable environment, that does not change*". The importance of variability in practice is found to be especially relevant in basketball, albeit only in jump-shots, which are open skills, as they are shots taken from various positions on the court and not only from one particular distance, though its relevance to the free throw, a closed skill as opposed to the jump-shot which is an open skill, is questioned (Struzik et al., 2014:216). Variable practice can also be seen as a type of practice in which execution/training factors are manipulated in order to change the set ways in which certain skills are practised (Breslin *et al*., 2012a:154). Variability in practice is also assumed to create a stronger and more flexible representation of the movement within its more general class of actions, compared to training in only a single skill (i.e. constant practice) (Breslin *et al*., 2012a:154).

An earlier study by Schmidt (1975:2003) also referred to variable practice as a more '*generalized*' practice as stated by Breslin *et al*. (2012a:154). It is believed that variations in training would promote transfer to unpractised skills in the same class of movement, governed by the same GMP, giving the participant the ability to perform equally well in different activities in the same class of movement (Breslin *et al*., 2012a:154; Shea & Kohl, 1990:172). In summary, these findings suggest that constant practice (i.e. specific) yields less accurate results and effective transfer abilities to other skills compared to variable practice (i.e. generalised) (Breslin *et al.*, 2012a:154). The benefits of variable practice were discussed in much earlier research by Magill (1989:403), who used two terms to increase understanding of variability in practice, namely *regulatory* and *non-regulatory* stimuli (Magill, 1989:402). Magill (1989:403) stated that it could be seen as movement-related information that remained constant throughout the execution (i.e. how to shoot a free throw) and other non-related information/stimuli that changed as the environment or conditions changed (i.e. opponents, venue, crowd etc.). When practising closed skills (i.e. free throw), the practice conditions should stay the same as in match-play, with regulatory stimuli remaining constant; however, non-regulatory stimuli should be changed throughout practice. This is an example of using variability in practising closed skills, thus creating similar game-like situations (Magill, 1989:404).

In open skills ("*shots taken in unknown circumstances with novelty variables present in different situations"*), these skills resort under novelty conditions; yet the players have to respond to the same situation more than once in the same way (Magill, 1989:404). Schmidt's research (1975) discusses the need to practise skills under variable conditions so that players could acquire the appropriate motor patterns for different novelties (Magill, 1989:404). (*More on this in section 2.5.2. – Schema Theory*). During his research, Magill (1989:406) recognised the importance of variability in practice for success under novelty conditions; however, he also stated that the amount of practice was still deemed important as well. The main benefit was that a strong recall schema was developed under variable conditions, which in turn would be beneficial during novelty situations (Schmidt, 1975; Magill, 1989:406).

The benefits of variable practice gave way to a study regarding the constant- and variable groups in the basketball free throw where the researchers compared the two practice conditions to determine if one or the other caused especial skill emergence (Breslin *et al*., 2012a:154). During this study, the constant group practised from only the 4.57 m distance and the variable group from a range of distances (Breslin *et al*., 2012a:155). The researchers stated that the performance from the free throw line would be better for the variable group compared to the constant group (Breslin *et al*., 2012a:155). Their results confirmed an increase in accuracy from the free throw line in both groups when comparing pre- and post-tests (before and after an intervention training programme), however, the accuracy increase were not significant ($p$ = 0.18) in either the constant or in the variable practice groups (Breslin *et al*., 2012a:156). *[Important to note, in our current study, a retention-test was used rather than a post-test, the main difference being that a post-test is a test <u>without</u> a no-practice period, with the test taking place immediately after the intervention period, while the retention-test has a no-practice period, focusing more on memory recall as to memory response as in post-test. Magill (2011) found that retention-tests bring about more permanent changes, as to post-tests focusing on immediate changes]*.

Only when comparing actual *vs.* predicted accuracy scores at the 4.57 m line was a significant difference noted in the constant practice group ($p$ < 0.05) (Breslin *et al*., 2012a:156). While Breslin *et al*. (2012a:156) reported that the emergence of the skill with a unique advantage was apparent after only 300 trials, contradictory studies (Keetch *et al*., 2005; Keetch *et al*., 2008; Simons *et al*., 2009) found that massive amounts of practice was needed to evoke especial skills. However, they (Breslin *et al*., 2012a:156) acknowledged that constant practice could evoke the emergence of increased performance in a specific skill, but not as a result of excessive time spent in training, as this advantage was observed earlier. Breslin *et al.'s* (2012a:156) comparison of these two distinct practice types had one main objective, namely to understand if either of the practice "conditions", led to the appearance of the remarkable skill and if so, which one.

Breslin and colleagues (2012a:156) found that the accuracy of the free throw in the constant group also increased from other distances not covered in training. This proves that there is generality within a class of actions as a result of more specific training from one distance (Breslin *et al*., 2012a:156). Similar arguments were stated by other researchers (Keetch *et al*., 2005:976; Keetch *et al*., 2008:724), who proposed that the recall schema of Schmidt (1975:247) became more refined with more practice of a specific skill within a group of motor skills. Breslin *et al*.'s (2012a:156) findings showed that the constant group did not have greater accuracy at the free throw line than the variable group, as suggested by a previous criterion (Keetch *et al*., 2005:976). It also substantiates the variability in practice hypothesis, even after practice at the specified distance was reduced by more than 80% (Breslin *et al*., 2012:156). However, they did not find signs of retention by the variable group over the constant group (Breslin *et al*., 2012a:156). The researchers concluded that massive amounts of practice were not needed at the 4.57 m line to evoke a specialised skill (Breslin *et al*., 2012a:156). Thus, only a more constant form of practice was needed over three training days to evoke this skill, supporting the previous research (Schmidt, 1975:247; Breslin *et al*., 2012a:156).

Rather than looking at the amounts of practice to attain a certain skill, researchers were advised to study the effect of practising different skills under different practice conditions, as the data failed to support, or reject for that matter, the hypothesis on why certain skills offered an advantage over other skills (Breslin *et al*., 2012a:154; Czyz *et al*., 2013:139; Keetch *et al*., 2008:735). The authors predicted that owing to the jump-shot not necessarily being trained from a fixed location, players would not yield any advantage at those specific locations in front of and behind the free throw line, or on the line itself. Instead, it was believed that the results would only show general effects at the different locations, with no uniqueness at all from the 4.57 m line (Keetch *et al*., 2005:974). Their hypothesis was supported, with no superior accuracy found at the 4.57 m line when evaluating the jump shot, as shown in Figure 3 (right-hand side of the figure) (Keetch *et al*., 2005:974).

The *'unique performance'* of the free throw (as opposed to jump-shot) from the free throw line in basketball, explicitly the 'outperformed shot proficiency' from the 4.57 m line, and the advantage of this particular shot over other shots, were ascribed to the term *'especial skill'* (Keetch *et al*., 2005:976).

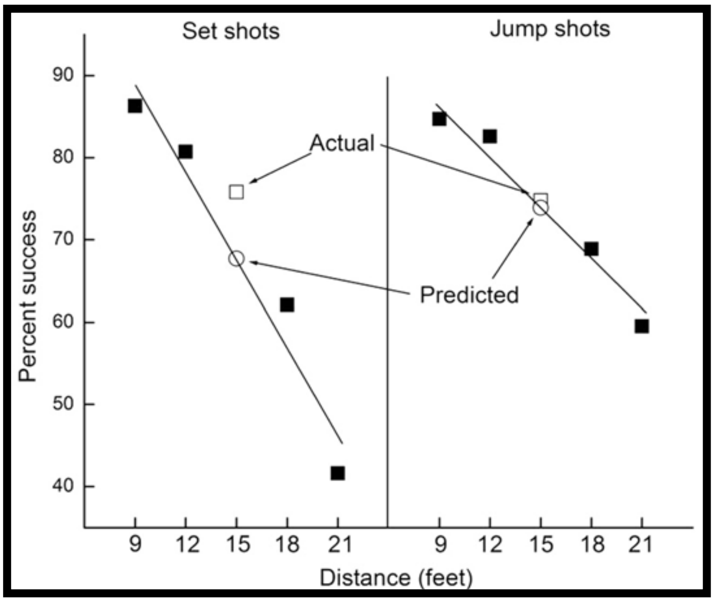


**Figure 2-3: Basketball free throw vs. jump shot**

*A comparison of the basketball free throw (left panel) (Experiment 2) vs. the jump-shot (right panel) (Experiment 3). In the left panel (i.e. free throw) one can see the emergence of an especial performance from the foul line (15 ft.), compared to the jump-shot where it is not present. (Keetch et al., 2005:974 – Figure 2; reprinted with permission)*

## 2.4 Definition of 'especial skills'

An especial skill can be defined as a specific skill with a special status within a more general class of motor skills, which as a result of massive amounts of practice, could be distinguished from the rest of the class by superior performance (Breslin *et al*., 2012b:338; Carson & Collins, 2016:7; Czyz *et al*., 2013:139; Czyz *et al*., 2015:143; Fay *et al*., 2013:709; Keetch *et al*., 2005:976; Keetch *et al*., 2008:735; Simons *et al*., 2009:469; Stöckel & Breslin, 2013:536). This definition of "especial" could be seen in dictionary terms as – "*an exception to the rule*", referring again to the uniqueness of this specific skill among other skills (Breslin *et al*., 2012b:338). Moreover, the emergence of the especial skill and the theories on why it emerged raised further interest in the field, broadening the perspective and knowledge found in Keetch *et al*.'s experiments (2005), with more research done on basketball free throws (Keetch *et al*., 2008; Breslin *et al*., 2010; Breslin *et al*., 2012a; Breslin *et al*., 2012b; Czyz *et al*., 2013; Czyz *et al*., 2015; Stöckel & Breslin, 2013), wheelchair basketball – free throws (Fay *et al*., 2013), baseball (Simons *et al*., 2009) and archery (Czyz & Moss, 2016; Nabavinik *et al*., 2017).

### 2.4.1. Emergence of "especial skills"

The above-mentioned studies' results strongly support the initial findings of Keetch *et al.* (2005:735) in their research on the basketball free throw. It was found that massive amounts of practice gave rise to skills clearly distinguished from others in the same class of skills, demonstrating performance distances in favour of these distinguished capabilities (Keetch *et al*., 2008:735). Though basketball research is limited (Keetch *et al*., 2005; Keetch *et al*., 2008; Czyz *et al*., 2013), a group of researchers shifted their focus to another sport-skill, the baseball pitch (Simons *et al*., 2009).

Their experiment involved baseball pitches from seven different distances, including the regulation pitching distance (18.44 m/60.5 ft.), and then three distances closer and further from the normal pitching distance (Simons *et al*., 2009:472). Their findings were consistent, demonstrating a negative relationship (distance increase *vs*. performance decrease) between the distance and the accuracy of the baseball pitch, from all non-regulation distances (Simons *et al*., 2009:472). However, this negative relationship did not occur at the normal pitching distance (18.44 m), where the said especial skill clearly emerged (Simons *et al*., 2009:475). Importantly, the results showed that pitchers only showed signs of the especial skill from the regulation pitching distance (18.44 m) (Simons *et al*., 2009:475).Their results indicated that the pitching success regarding accuracy was significantly ($p < 0.05$) greater from the regular pitching distance (the regular pitching distance mound of 18.44 m) compared to other distances measured (Simons *et al*., 2009:474). Pitching accuracy from the 18.44 m mark resulted in practically and statistically ($d = 0.8$ ; $p < 0.05$) greater values compared to the predicted values, overcasting data from distances ranging from 11.12 m to 25.75 m (Simons *et al*., 2009:474).

Interestingly, Breslin and his co-authors (2012b:340) questioned the fact that Simons and associates (2009) studied the especial skill effect by omitting much of the "real-world" contextual cues, doing their experiments in a gymnasium and only a target, with no baseball field associates, such as the "home-plate". However, they (Breslin *et al*., 2012b:340) did compliment Simons *et al.*'s (2009:472) research design referring to the importance of the inclusion in their experiment of specifically two of the seven distances/locations, 1 ft. shorter (59.5 ft.) and 1 ft. further (61.5 ft.) than the regulation pitching distance (60.5 ft.). As mentioned, pitchers only showed signs of the especial skill from the regulation pitching distance (i.e.18.44 m), but not from the two aforementioned locations, which were only slightly closer or further (Breslin *et al*., 2012b:341). Their results, therefore, support the hypothesis that massive amounts of practice from the normal pitching mound was probably the leading cause for the emergence of the especial skill at this distance, supporting earlier findings (Keetch *et al*., 2005; Keetch *et al*., 2008) in previous experiments on the basketball free throw (Simons *et al*., 2009:475). In contrast to this, three recent studies (Breslin *et al*., 2012b:341., Czyz *et al*., 2013:148; Czyz & Moss, 2016:9) did not support the notion that massive amounts of practice would cause especial performance, as the researchers found especial skill emergence in less experienced participants. However, Czyz *et al*. (2013:148) stated that their results reported a linear pattern when looking at the shots from the inexperienced players, supporting the findings of much earlier reports that linear relationships exist in force production and the variability thereof (Schmidt *et al*., 1978:195).

During Czyz and Moss's study on archery (2016), they reported that even with training variations from four different distances (30, 50, 70 and 90 m), though still specific, no especial performance was evident (Czyz & Moss, 2016:9). However, a significant difference ($p < 0.05$) was noted at the 70 m mark between actual and predicted values (Czyz & Moss, 2016:9). They argued that this significant difference might be due to the 70 m archery competition being a distinguished event, archers logically undertaking extra training at this distance (Czyz & Moss, 2016:9). Yet, because of mere speculation on this matter, their question remained unanswered: why did especial performance emerge at the 70 m distance if they trained from all four distances (Czyz & Moss, 2016:9). Nabavinik *et al*. (2017:4) supported generality of the especial skill phenomenon as found by previous researchers (Keetch *et a*l., 2005; Keetch *et al*., 2008; Breslin *et al*., 2012a; Breslin *et al*., 2012b), however, it was in direct contrast to that of Czyz and Moss (2016), even though they tested for especial skill emergence in both studies using archery – a sport using much less movement variability than basketball (Keetch *et al*., 2005) and baseball (Simons *et al*., 2009).

However, the biggest difference, and probable reason for one study supporting the especial skill effect and the other contradicting, was the distance factor. Nabavinik *et al*. (2017:4) had a maximum shooting distance of 21 m, whereas Czyz and Moss' (2016:9) minimum distance was from 22 m up to 90 m. The difference found in especial skill emergence could be as a result of the difficulty that is long distance shot present in Czyz and Moss' (2016) study, or it could be the increased practice at the 18 m distance in Nabavinik *et al*.'s (2017) research study. Since a number of reasons have been advanced for the cause of especial skills, the researcher considered the main existing hypotheses.

### 2.4.2. Hypotheses on especial skill emergence

*The following table (Table 2-1) discusses the hypotheses that proposed possible mechanisms for especial skill emergence as stated by several authors. Although these hypotheses are stated in the following the table, only the main hypothesis as formulated by Breslin et al. (2010:56) is discussed.*

**Table 2-1: Hypotheses on especial skill emergence**

| **HYPOTHESIS (ORIGINALLY PROPOSED BY)** | **THEORETICAL FRAMEWORK/THEORETICAL BASIS FOR THE HYPOTHESIS** | **HYPOTHESIS TESTED BY** |
|---|---|---|
| Learned Parameter Hypothesis, also called Parameter-Specification Hypothesis (Keetch *et al*., 2005) | This theory stated that extensive amounts of practice in a specified skill facilitated the performance parameters (spin, velocity, angle etc.) to become highly specified and the result was a distinguished shot among other throws – the *free throw* shot. Thus, by using a GMP (Schmidt's Schema Theory – 1975), which is said to be a motor programme governing the entire class of actions, these trained parameters will be selected automatically when the movement is performed. | **Confirmed:** Breslin *et al*. 2010 **Rejected:** Keetch *et al*. 2008 **Equivocal:** Stöckel and Breslin, 2013 |
| Visual-Contextual Hypothesis (Keetch *et al*., 2005) | This refers to the relationship that exists between the performance of a skill and the visual clues that are present during execution of the skill, which is information that stays constant during practice. Therefore, as learning progresses and becomes more advanced, the dependency on this visual feedback becomes more important. In the experiment of Keetch *et al*., (2005 – experiment 2) where this hypothesis was tested, a product of practice indicated a remarkable degree of specificity in the basketball free throw. Furthermore, their results raised the question of a possible hypothesis of a "specific-motor-programme". | **Confirmed:** Breslin *et al*. 2012a; Czyz *et al*. 2015; Keetch *et al*. 2008 **Rejected:** Keetch *et al*. 2005 **Equivocal:** Stöckel and Breslin, 2013 |
| Specific-Motor-Programme Hypothesis **or** Especial GMP (eGMP) Hypothesis (Keetch *et al*., 2005) | Also referred to by Czyz *et al*. (2013) as an especial GMP (**eGMP -** i.e. original name given by Keetch *et al*., 2005), this revolves around the theory that after massive amounts of practice of a certain skill, a new, separate motor programme will eventually be formed for that specific movement. | **Rejected:** Breslin *et al*. 2010 |
| Self-efficacy/Self-confidence Hypothesis (Simons *et al*., 2009) | Based on the social-cognitive theory of Bandura (1977; 1984), this theory predicts that through extensive amounts of training, the participant's self-confidence will increase and facilitate the performance of the especial skill. | **Rejected:** Simons *et al*. 2009 |

Four possible explanations can be considered to reach clear understanding of exactly what causes the emergence of especial skills:

- Firstly, the research examined massive amounts of practice at the specific distance within a general class of skills, labelled the "learned parameter hypothesis/parameter-specification hypothesis," thus the different parameterisations of velocity, spin, angle etc. that helped form the immensely specified movement in the free throw (Keetch *et al*., 2008:729).
- Secondly, the "visual-context hypothesis" was considered, where the floor markings of the seven different distances were closed in the free throw experiment to see whether the players made a visual connection to the distance from the basket and their ability to succeed in the shot (Keetch *et al*., 2008:729). Unfortunately, this specific hypothesis (i.e. visual-context hypothesis) failed to be proven as a reason, because the advantage at the 4.57 m line still existed (Breslin *et al.,* 2010:55; Keetch *et al*., 2008:727; Stöckel & Breslin, 2013:540). The researchers did, however, concur that because of the consistent position of the free throw shot and the same angle and visual distance from the basket, memory representations could have attributed to the results noticed (Breslin *et al.,* 2010:55; Keetch *et al*., 2008:730).
- In a third major assumption, Czyz *et al*. (2013:148) talked about the "specific-motor-programme hypothesis", also known as the eGMP. Their experiments followed the same procedure as those of Keetch *et al.* (2005 – Experiment 1), where the participants had to shoot free throws from seven different distances. They suggested that once a skill was declared an especial skill, it would be able to generalise to nearby distances (Czyz *et al*., 2013:148). However, their main findings contradicted the first study on especial skills (Keetch *et al*., 2005), with the reported results providing much less generalisation/variance in shot proficiency (Czyz *et al*., 2013:148). They also found a lower level of uncertainty in motor function from the free throw line, as reported by their 'Bayesian' statistical model (Czyz *et al*., 2013:148). In contrast to previous studies (Keetch *et al*., 2005; Simons *et al*., 2009; Breslin *et al*., 2010), Czyz and his team (2013:148) supported the hypothesis of generalisation and stated that the amount of practice, not necessarily the years of practice, was important for especial skill emergence. However, they noted that together with the amount of practice, the type of practice should be the main aspect of focus (Czyz *et al*., 2013:149). Czyz *et al*. (2013:149) supported the assumption that a massive amount of practice was not needed for the emergence of especial skills; rather it brought about better shot proficiency at the 4.57 m line.

Simons and his co-workers stated that in their experiment on the baseball pitch, they spoke of a hypothetical "eGMP" existing for the regular pitching distance of 18.44 m, which acted independently from the normal GMP in baseball pitching.

- Fourthly, Simons *et al*. (2009) focused on another hypothesis, namely the "self-efficacy/self-confidence" hypothesis. Based on the socio-cognitive theory of Bandura (1977:1984), this hypothesis is built on the prediction that through extensive amounts of training, a person will gain a lot of self-confidence in performing this action, which will facilitate the performance of that skill going forward (Simons *et al*., 2009:475). However, the results reported no difference with regard to the efficacy of the players at the regular pitching distance rather than other distances in the experiment (Simons *et al*., 2009:475). Thus, the players did not confirm any higher levels of confidence at the 18.44 m line than at the other distances, proving their initial assumption false (Simons *et al*., 2009:475). They stated that no evidence was found in support of their hypothesis, and that confidence could not be seen as a determinant for the emergence of the especial skill. They consequently rather asked the question of an 'especial GMP (eGMP)' (Simons *et al*., 2009:477).

After further analysis of what their (Keetch *et al*., 2008:730) research reported, stated that if the emergence of the especial skill was a result of the "parameter-specification hypothesis", the accuracy rate from the seven locations would be consistent and be relatively similar, as the parameters correlated (angle of shot, distance to basket, velocity). In contrast, if the accuracy at the 90° angle (original free throw position) was higher than at the other six locations, they could confirm that it was in fact as a result of the visual-contextual information picked up by the players during their accumulated practice of the free throw, confirming their visual-context hypothesis (Keetch *et al.*, 2008:730). This is supported by the findings of later research (Stöckel & Breslin, 2013:540), stating that parameterisation alone could not account for the emergence of the especial skill, as some (Breslin *et al*., 2010:60) suggested.

Further analysis of these results (Stöckel & Breslin, 2013:540) provided evidence contradicting the "learned parameter hypothesis" (Keetch *et al*., 2008:731). The original assumption suggested that training from the 15 ft. shot from the free throw line created a specialised parameterisation memory representation within the GMP (*GMP's discussed further in **2.5.2***) (Keetch *et al*., 2008:731). Consequently the practice accumulation was making the parameter memory selection for the free throw shot more accurate (Keetch *et al*., 2008:731). However, if this was the case, then the accuracy from the other six locations should have stayed more or less constant, as the parameters stayed constant (Keetch *et al*., 2008:732). On the contrary, their results on shot proficiency showed a significant rise ($p < 0.05$) in the shot accuracy from the free throw line compared the rest of the less-accurate shots (Keetch *et al*., 2008:732). This indicated a separate memory representation (i.e. eGMP) from the rest of the locations – more specific than simply part of a generalised parameter group (Keetch *et al*., 2008:732).

Therefore, if the angle from the basket fell into a more generalised class of effects, one could argue that as the angle from the basket increased (moved further from the free throw line), the performance would also decrease (Keetch *et al*., 2008:733). The data failed in its attempt to reject the learned parameter hypothesis completely in the sense that the free throw especial skill emerged solely as a result of learned information from this location, and tended to support an argument that the specificity of the free throw was, at least in part, due to learned sensory-motor specificity (Keetch *et al*., 2008:733).

The fourth possible explanation proposed that the uniqueness of the especial skill was attributed to the "specific-motor-programme hypothesis/eGMP" (Breslin *et al.*, 2012b:344; Breslin *et al*., 2010:56). The hypothesis stated that the player would not use his/her GMP as suggested in the "schema theory" (Schmidt, 1975; 2003) (*schema theory discussed in* ***2.5.2***), but rather a specific motor programme for the free throw movement (Breslin *et al.*, 2012b:344). This prediction was that if relative timing patterns differed from the free throw line *vs.* the other four distances (i.e. two closer; two further), a separate and specific memory representation would be created for the free throw, but not for the others – thus, separate from the GMP (Breslin *et al*., 2012b:344).

Breslin *et al.* (2010:57) tested this hypothesis, adapting the experiment used by Keetch *et al.* (2005), shooting free throws from five different distances, this time changing the type of ball used, manipulating it by making it heavier. In the experiment the weight of the ball was manipulated, with all shots taken from varying distances, half the shots being taken with a regular basketball and the other half with the heavier ball (Breslin *et al*., 2010:57). The heavier ball would force the athlete to use other parameters (more force; higher release angle; less spin on the ball) for that shot than the parameters he would use for the normal-weight basketball shot (Breslin *et al*., 2012b:344).

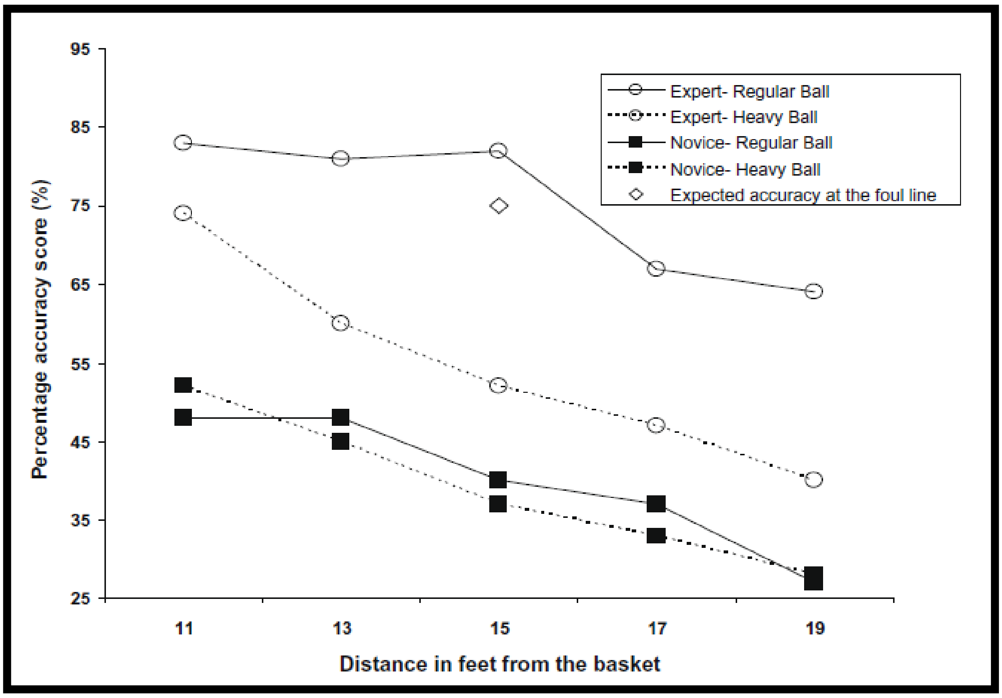


**Figure 2-4: Basketball free throw with regular ball vs. heavier, irregular ball**

*Accuracy of the set-shot taken from five different distances by expert and novice basketball players, with a standard basketball and a heavier ball (i.e. non-standard) respectively. A regression analysis shows the line set up using the three shortest and longest distances. (Breslin et al., 2010:59 – Figure 2; reprinted with permission)*

The results (Figure 2-4) show the absence of the advantage from the free throw line once the non-regulation ball was used (no especial skill emergence) (Breslin *et al.*, 2010:57). This proved that massive amounts of practice gave rise to a distinct advantage in this particular shot, though this was expected, as the elite players had no training experience with the heavier ball at the free throw line (Breslin *et al.*, 2010:57). Breslin *et al.* (2012b:348) favoured the learned parameter hypothesis, giving credit to the visual-context hypothesis as well. If supporting evidence existed for only one class of motor skills — the basketball free throw — the case built against the existence of especial skills would have been strengthened; however, this is not the case (Keetch *et al.*, 2008:733; Stöckel & Breslin, 2013:540).

In another attempt to find a reason for the emergence of especial skill, one distinction was made in reference to closed skills and open skills, which were defined as: "*where changing variables was limited to only a few" and "where outside variables could alter and be unpredictable*" (Keetch *et al.*, 2005:976). Keetch *et al.* (2005:976) wanted to determine whether especial skills were more to be expected in closed skills, or whether it was possible to acquire these especial performances during open skills practice, as massive amounts of practice would be required for the occurrence of especial performance during the latter (Keetch *et al.*, 2005:976).

Emphasis on especial performance in open skills suggested that people do not possess many of these distinguished skills (Keetch *et al*., 2005:976) and thus, acquiring an especial skill would not prove problematic to "motor skill memory", as suggested by Schmidt (1975:241). Further research on different tasks regarding especial performance was undertaken, looking at tasks with definitive beginning and end points, supporting real-time situations where variability in practice and game situations are limited (Keetch *et al*., 2008:735). It is, however, predicted that the development of an especial skill would be possible in more game-play situations where one skill should receive superior training time/trial, thus, where the importance of a skill is far greater than the rest of the skills in the same generalised class (Keetch *et al*., 2005:976).

After considering research regarding the type of practice (i.e. more specific or more variable) and massive amounts of practice, little clarity was achieved as to what exactly formed these especial skills. A more definite question of generality and specificity between actions arose, which would shed more light on the aspect of focusing only on a single skill, or rather a group of skills that form part of the same class of actions (Czyz & Moss, 2016:10).

### 2.5. Motor learning and -control.

According to Keetch *et al.* (2008:723) the existence of generality and specificity in effective motor programmes could be explained by the earlier studies of Schmidt (1975:2003). A memory representation of motor learning, known as a motor programme, is seen as a 'memory based construct' that controls and coordinates movement (Magill, 2011:90). Motor learning, as defined by Magill (2011:3), focuses on "*the acquisition of motor skills, enhancing and improving motor skills and the reacquisition of skills after injury or disease*".

Motor skills, on the other hand, are defined as "*activities or tasks that require voluntary head, body, and/or limb movement to achieve a specific purpose or goal*" (Magill, 2011:3). Whereas motor learning is focused on the acquisition of motor skills, motor control is focused on how the muscles and limbs are controlled and activated by the neuromuscular system when a motor skill is being performed (Magill, 2011:3). With this being said, Magill (2011:90) believes that among the viewpoints of many researchers, the one that undoubtedly sets and characterises the way researchers think about motor programmes today, is the research by Schmidt (1975; 2003). Schmidt's (1975) schema theory proposes that previous research limited a motor programme to only one specific movement or a sequence of movements (Magill, 2011:90).

2.5.1 Generality vs. specificity.

Stöckel and Breslin (2013:536) emphasised the coexistence of generality and specificity of practice in the development of a memory representation for a certain class of action, supporting previous findings (Keetch *et al*., 2005:972) and more recently, Nabavinik *et al*. (2017:4) who reported findings that strongly supports generality in especial skill emergence in skills that are highly trained. Henceforth, an advantage identified during the free throw was the specific component within the memory representation of set-shots that increased performance accuracy whenever the shot was taken from the foul-line (Breslin *et al*., 2012b:338). The generalised form of memory representation allowed players to shoot the free throw from different distances with sufficient ability (Keetch *et al*., 2005:972).

Apart from generality in motor programmes within memory representations, the focus was also placed on the specificity of movements and the effect of this in different theories of motor control (Keetch *et al*., 2008:724). According to Keetch and her colleagues (2008:724), previous research revolved around specific motor skills, manipulated to test for retention and transfer and often using constant conditions in retention and transfer similar to those in the acquisition phase of the specific skill. They then compared original test results in constant conditions, to manipulated condition testing, focusing on the type of practice and test itself (Keetch *et al*., 2008:725). One of the key principles to understand is what a condition can be defined as, and if changed, what the effect would be on motor skill performance (Keetch *et al*., 2008:725). Magill (2011:371) reported that variability in practice would give the player the ability to perform the skill under practice conditions (i.e. circumstances present during practice) and novel conditions (i.e. circumstances or situations that may occur in future competitions or matches). Hence, constant practice (i.e. specificity in practice) conditions would entail that only one variation of the skill would be performed under the same conditions every time, whereas variable practice (i.e. generality in practice) conditions refers to situations where several variations of a skill are performed (Magill, 2011:371).

Therefore, understanding that conditions are the circumstances / situations present when performing a skill under / in its normal environment as it is always performed in competition, or when it is not manipulated in such a way that it differs from its original environment (e.g. a free throw from distances other than the 4.57 m line) (Keetch *et al*., 2008:725). Similarly, home-field advantage in sport shed light on the principle of context specificity, in which task-related information stays the same as in skills training; thus, it is said to be the key issue in making the home-field advantage a possible factor of success in sport (Keetch *et al*., 2008:725). This means that the processing information is promoted by the conditions of the test if it is indeed the same as in training — a strong supporting statement for training specificity (Keetch *et al*., 2008:725).

According to the author's knowledge, Adams (1971) is the only study at the time supporting the closed-loop theory, where he explained that the acquisition of a skill could be seen as the learning of a specific memory representation (Keetch *et al*., 2008:725). To understand Adams's theory (1971), good understanding of "closed-loop" and "open-loop" systems is necessary. Open-loop and closed-loop control systems exist as the two basic systems that are in charge of motor control in the body (Magill, 2011:88). One of the main differences between the two control systems is "feedback", which according to Magill (2011:89) is information from the sensory system indicating the status of movement. Closed-loop control systems use this feedback to compare the movement to a set standard and correct it if it is not on par with this standard/reference, while open-looped systems depend on the information in movement instructions to carry out the desired movement (Magill, 2011:89). According to Krigolson and Tremblay (2009:197), players tend to shift from closed-loop to open-loop mode of movement and motor control. They, in turn, defined closed-loop theories as movements with sensory feedback, while open-looped theories were those without feedback (Krigolson & Tremblay, 2009:197; Magill, 2011:89), which they attributed to Schmidt's schema theory (1975: 2003).

Adams's (1971) closed-loop theory in motor learning, used "perceptual traces" as a referent in movement; meaning that these perceptual traces would serve as a model that would test the correctness of the executed movement (Magill, 1989:80). These traces were in essence seen as memory storage from past executions of a certain skill, hence, a referent to how the movement is executed (Magill, 1989:80). It is dependent on feedback, as the movement progresses during the execution process, giving feedback through sensory pathways (Magill, 1989:81). The perceptual traces are responsible for comparing how the movement is executed at present, and how it was previously stored. If not similar, it is altered and adjusted to fit the original trace, as the accuracy of these adjustments are dependent on the original trace's development (Magill, 1989:81). This is deemed vital, as the more the movement is practised, the stronger these traces develop, emphasising the importance of practising this process extensively (i.e. massive amounts of practice) (Magill, 1989:81). In addition, the stronger the trace becomes, the closer the player comes to generating that specific movement as an automatic response (Magill, 1989:81).

Keetch *et al*.'*s* (2008:725) appraisal supported Adams's research (1971), stating that practice caused an increase in perceptual strength. This demonstrates that the more training, the less generalised representations are present, and thus the more clearly specific traces are represented in the memory, leading to the possibility of generality and specificity coexisting in learning (Breslin *et al*., 2012b:339; Keetch *et al.*, 2008:725). Keetch *et al*. (2008:727) set out to test and prove their theory of coexistence by using an experiment in which one movement within a more general class of actions (i.e. free throw) was practised more than others in the same class (i.e. basketball shots in general). Becoming trained in a certain skill is evidence that sport participants have motor performance capabilities in both the general and specific sense (i.e. coexist), and as their research proved, the basketball set-shot (i.e. free throw), was an example of a skill that possessed this ability. During this experiment, they followed similar procedural steps to that of an earlier study (Keetch et al., 2005) where the players had to shoot free throws from seven different distances, shooting a total of 210 shots (30 shots per distance).

In addition to Adams's (1971) research rendering the closed-loop theory, Breslin *et al.* (2012b:339) research investigated the aspect of motor feedback that each person received, and stored accordingly in memory, after executing a planned goal-directed movement. The more a particular / specific action were trained in practice, the more memory representations would emerge for that respective skill or movement, and thus, a perceptual histogram would emerge (Breslin *et al*., 2012b:339). This *"frequency histogram"* changes as the skill is practised, with the correct/dominant perceptual traces (i.e. memory representations) strengthened, while the non-dominant/incorrect traces weakened (Breslin *et al*., 2012b:339). Thus, a skilled movement or action would result if a single feedback memorised representation dominated the stored presentations, and acted as the default programme for the correct execution of the desired movement (Breslin *et al*., 2012b:339).

The research by Adams (1971) was thereby supported by Breslin *et al.* (2012b:340), who stated that the strengthened motor programmes would cause athletes to execute movements correlating with the feedback of an executed movement, as a result from the feedback of the original memory trace. Accordingly, the movement was said to be controlled in an automatic system response (i.e. closed-loop way) (Breslin *et al*., 2012b:340; Krigolson & Tremblay, 2009:197). Therefore, current feedback of a performed action was assessed in terms of the original movement representation in memory (Breslin *et al*., 2012b:340).

The assumption existed that all skilled movements would be represented in memory by a single, specific memory trace, as Adams's (1971) research stated (Breslin *et al*., 2012b:340). However, generality in motor control suggests that various methods can be used to perform a certain skill(s), which poses a threat to only one stored memory trace for a single movement (Keetch *et al*., 2008:723). However, the schema theory of Schmidt (1975) clearly states otherwise. In the end, it was predicted that each action within a general class of actions would have an additional refined memory "space" as a result of the more specific practice of that skill (Breslin *et al*., 2012a:156). Not only did this implicate the research of Adams (1971), but the existence of this distinctive skill (i.e. basketball free throw) among other skills in the same general class of movement actions (i.e. other shots and set-shots) also posed a real threat to the better known theories of motor control, such as the well-known "*schema theory"* hypothesised and introduced by Schmidt (1975) (Keetch *et al*., 2008:728).

2.5.2. Schmidt's schema theory and generalized motor programmes (GMPs).

Magill (1989:81) shed light on a few limitations regarding the 'closed-loop theory' of Adams (1971) which were also recognised earlier by Schmidt (1975). One limitation was that the closed-loop theory was too limited to act as a motor programme that responded to more than slow and simple movements (Magill, 1989:81; Shea & Wulf, 2005:86). Another limitation stated by Schmidt (1975) was the logical problem of how players would select a proper response to an incorrectly executed movement, which did not correspond to the original trace, if they never performed the movement under other circumstances (Magill, 1989:81). In this regard, Schmidt (1975:239) stated that no specific memory representation could exist for a single skill; thus, no distinct skill could exist within a general class of actions, omitting the possibility of specificity in skills.

Furthermore, Schmidt (1975:242) noted that one class of motor skills is represented by a single representation, known as the GMP, which also stores the unchangeable features of any given movement, which was later supported by other research findings (Keetch *et al*., 2008:724; Magill, 1989:149). Moreover, more recent statements (Magill, 2011:91) regarding the original reports of Schmidt (1975:242), which argued that the GMP associated with each movement was the proper mechanism behind the highly adaptive and rather flexible quality traits in human abilities/skills. This GMP controls an entire class of actions rather than only one movement or movement collection; hence, it is the basis to control an individual action in that class (Magill, 2011:91).

According to Magill (2011:91), Schmidt defined a class of actions as *"a set of actions that shares common characteristics"* even though the actions themselves were different. These unique characteristics were referred to as 'invariant features', and were seen as the foundation of the stored memory representation of a certain movement (Magill, 2011:91). Schmidt (2003) called it the fundamental pattern of the class of actions. Thus, these invariant characteristics remained similar throughout a movement within a class, and when a specific movement needed to be performed, these parameters were used from memory, and then movement-specific parameters were added to these stored invariant parameters (Magill, 2011:91). Parameters, usually referred to as movement parameters, can be seen as the characteristics of a GMP that can vary from one skill to another, but moreover, are the features of specific skills that must be added to the invariant features that are unique to that skill's GMP, so that a person can perform a specific movement action (Magill, 2011:91).

This was seen as an important limitation, as Adams's theory (1971) did not atone for the complexity of a class of motor skills. Accordingly, a class of motor skills could be defined as a set of movements within the same general class of action, sharing similar core characteristics, such as relative timing sequences, relative force and order of sequence (i.e. invariant features) (Keetch *et al*., 2008:724; Magill, 1989:149; Magill, 2011:91). It was in light of the above-mentioned limitations and in an attempt to explain the operation of a GMP, that Schmidt (1975) created a new theory for motor control – the *'schema theory'* (Magill, 1989:82; Magill, 2011:91 Schmidt, 1975). In contrast to the findings of Adams (1971), which stated that traces were formed and used as a response mechanism, Schmidt (1975) proposed a schema that was defined as 'a governing body that serves as the foundation/basis of decision making' or 'an abstract representation of rules governing movement' (Magill, 1989:82; Magill, 2011:91). The schema existed as a result of information relating to one another in a similar class, thus, creating a general concept for different abstracts within the same class (i.e. a free throw is a shot among other basketball shots) (Magill, 1989:82; Magill, 2011:93).

The schema theory comprised two important components regarding motor control; firstly, the GMP, that controls the movement patterns and coordination thereof to perform a skill, and secondly, the response schema, which was referred to by Magill (2011:94) as the motor response that provides the parameters to the GMP, thus the rules governing a specific skill in that particular situation. Magill (2011:94) praised the fact that Schmidt's schema theory (1975) provided a proper explanation for how people could perform a particular movement successfully without having performed it previously; hence, the way one experiences a specific movement action at a particular time is different from how one has ever experienced it before. It is possible for a person to perform the movement appropriately and successfully in the new situation because he/she is able to use rules from the response schema to generate the appropriate movement parameters, which are added to the GMP to perform a movement (Magill, 2011:94). Thus, the GMP and response schema work together to generate an appropriate action response (Magill, 2011:1994).

Even though these processes of the GMP and response schema work together in an open-loop control system (i.e. many variables without feedback), once the movement is in progress, feedback to the system can be used to alter movements – so that, one uses both open- and closed-loop control systems (Magill, 2011:94). More specific to basketball, Keetch *et al*. (2008:724) and Magill (1989:82) focused on overhead throwing actions, which can be seen as a single class of motor skills, as the invariant features are similar, exist in all associated movements regarded as overhead throwing actions and are involved in producing the desired movement. Hence, a schema is formed, which would allow players to use this as basis/reference for any overhead throwing action (Magill, 1989:82). The schema theory reinforces the development of the generality concept (Schmidt, 1975:231) and assumes the existence of two separate schemas (Magill, 1989:82; Schmidt, 1975:242), namely:

- the "*recall schema",* which is responsible for the selection of a proper response to the supposed executed movement and gives the appropriate instructions to the motor programme generating a response (Magill, 1989:82; Schmidt, 1975:244). According to this schema (Schmidt, 1975:244), whenever an attempt is made to perform an action, the participant retrieves the relevant GMP for that class of actions, and then gathers additional parameters to suit the environmental demands present in that situational time.
- the "*recognition schema"*, allowing a player to compare the appropriate/correct response to the response relevant to the present sensory feedback, thus, to evaluate the correctness of movements (Magill, 1989:82).

A supporting base for the schema theory was the advantage that the proposed GMPs would provide (Magill, 1989:83). This suggests that the GMP would be able to select and execute the appropriate response to a novel or unknown circumstance, strengthened even more by means of practice (Magill, 1989:83). In other words, if a person is good at one variation of a motor skill, he would be good at all variations of that skill (governed by the same GMP) (Magill, 1989:295). The schema theory of Schmidt (1975) was based on the notion that a single motor programme controlled the basketball shot at all the different locations, including the shot taken from the free throw line (Breslin *et al*., 2012b:339). Breslin *et al*. (2012b:345; 2010:57) stated that a player's ability to shoot a free throw and to adapt its GMP improves with training and repetition; hence the same GMP is used in all shots with only a more refined parameter selection occurring at the free throw line. A single trained GMP will therefore have a positive effect on other shots governed by the same GMP (Breslin *et al*., 2012b:346; Breslin *et al*., 2010:58; Keetch *et al*., 2008:731).

According to literature, a single motor programme could provide the body with the necessary movement parameters to adapt to variable changes, such as distance from the basket (Breslin *et al*., 2012b:339). This important aspect of motor control is consistent with the view that the memory representation of a certain motor skill should be generalised, creating a GMP that would prevent and potentially solve the two limitations of motor control mentioned below (Breslin *et al.,* 2012b:339). The linear relationship performance (success percentage) of the shots taken from the other non-free throw locations (six other distances in Keetch *et al.,* 2005:972 in Experiment 1) and other notable generalisability in motor learning are examples of questions that the schema theory could account for ( Breslin *et al.,* 2012b:339).

In conclusion, a single GMP or memory representation possesses the fundamental characteristics of an entire class of movements, with the recall schema supplying the GMP with details for a specific situation (Keetch *et al*., 2008:724). Therefore, it can be seen that only two separate generalised representations (GMP and recall) eradicate the need for each movement having its own memory representation (Keetch *et al*., 2008:724). Keetch *et al*. (2008:734) stated that a convenient measure to differentiate the GMPs is analysing the invariant features (i.e. relative timing) of each shot through kinematic analysis (i.e. biomechanics), similar to a recent study done on basketball (Breslin *et al*., 2010).

## 2.6. Biomechanics.

Not only can biomechanics be applied to assess and prevent injuries; it is deemed vital for the success of a particular skill by making use of its kinematic (*discussed and defined in **2.6.2.***) parameters and combining functions (Miller & Bartlett, 1993:285-293). In this regard, the biomechanical analysis can be used to describe different mechanisms, such as the overhead throw action in netball (Hetherington *et al*., 2009:244), and has even been described much earlier in sports such as basketball (Miller & Bartlett, 1996).

### 2.6.1. Equipment used for kinematic recording and analysis.

In order to support the above-mentioned reports regarding the use of biomechanical analysis, kinematic analysis *procedures* should be in place. Typical procedures of kinematical measures include marking different body parts with reflection tape, distinctive marking pens or light-reflecting balls, and light-emitting diodes (Magill, 2011:33). These procedures then involve recording the person's movement using special cameras and motion analysis software (e.g. Qualysis camera system; Xsens-MVN; Vicon), and analysing these movements using the associated motion analysis software formerly named (Magill, 2011:33). Other procedures involve tracking the movement of an object associated with the person moving/holding the object, thus tracking a specific task (Magill, 2011:33). Chen (2014:478) used cameras that recorded basketball shots three-dimensionally at a speed of 50 frames per second, matching the speed of the movements.

Moreover, the importance of using specialised equipment for recording/analysis is seen in several studies, such as that of Button *et al*. (2003:266), who focused on the importance of the elbow joint in basketball free throws. The reason for using this particular joint (the elbow), was deemed important by Button *et al*. (2003:266); they found, among others, that of all the joints associated within the free throw movement, the elbow joint displayed the greatest angular motion during the propulsion phase of the free throw execution. Furthermore, Miller and Bartlett (1993:288) found that the average release angles from medium-range distances (3.66 m to 5.49 m) and long-range distances ($\geq$ 5.49 m), would be $47.8 \pm 5.8°$ to $51.9 \pm 5.4°$ respectively, with the release speeds increasing as the shot-distance increased significantly. In addition, a height of 2.75 m and a distance of 4.57 m away from the basket would require an approximate release angle of 46.5° (Miller & Bartlett, 1993:289).

Another study acquired the data with kinematic recordings through three-dimensional video recordings, also focusing on free throws by using motion reality systems and specific software for analysis (Schmidt, 2012:363). The researchers used joint markers to determine angular displacement and angular velocity, through recording the first five free throws of each participant, and portraying the person as an animated stick figure (Schmidt, 2012:363). Considering other sport, a kinematic model through biomechanical analysis for the hurdling athlete, Colin Jackson, has been completed (Coh, 2003:38). They reported the importance of the stride length before and after the clearance of the fourth hurdle in a 110 m hurdle race, emphasizing the importance of entire body movements during hurdling (Coh, 2003:44). In addition, upper body movements, including both shoulder movements and trunk flexion, created optimal trajectories for favourable landing conditions after clearing the hurdle (Coh, 2003:44).

More specific to basketball free throws, in reference to overhand / overhead throwing, kinematic analysis provided an effective means of using video footage and kinematic recording to calculate strength ratios in the shoulder and arm of a netball player during an experiment (Hetherington *et* *al*., 2009:250). From using the kinematic analysis they could pick up that the maximum velocity during the speed was in fact not at the point of ball release but rather 40ms after a point of maximum velocity (Hetherington *et al*., 2009:250). Furthermore, by considering both the kinematic and kinetic data from the force plate used in this experiment, they reported that at ball release, the force exerted by the front foot was the highest, and lastly shed light on the possibility of understanding knee injuries in netball, and stated that the reports from this study could help determine true efficiency and technical skill in the netball shoulder pass (Hetherington *et al*., 2009:252). Accordingly, kinematics has become an important descriptor of performance in motor learning and control, useful for researchers to do more in-depth and in-detail analysis (Magill, 2011:33; Magill, 1989:30).

2.6.2. Kinematic analysis as a tool to assess and characterise generalized motor programmes (GMPs).

Kinematics, which is more generally associated with the term biomechanics, refers to "*the description of motion without regard to force or mass*" (Magill, 2011:33; Magill, 1989:29). Kinematic measurements are done by recording certain movements of different body segments while performing a particular skill, referred to as 'performance production measures' (Magill, 2011:33). It comprises various kinematic variables (such as displacement, acceleration, velocity, release velocities, take-off angles, movement parameters, acceleration of different objects and the determination of sport-specific components and skills) (Hetherington *et al*., 2009:244; Magill, 2011:33; Schade, 2010:29). Kinetics, on the other hand, is "the consideration of force in the study of motion", seeing it as the cause of motion (Magill, 2011:36). Rotation of joints and their joint axes is an important related characteristic of kinetics, also referred to as torque or rotary force (Magill, 2011:37). Even though their research did not distinctly focus on biomechanics or kinematics, Fay *et al*. (2013:708) stated that kinematic motion parameters might help create a method to accurately predict and train for especial performance in sport, and in the coaching world regarding different aspects and mechanisms of movements in sport (Schade, 2010:28; Dobovicnik *et al*., 2015:11).

The use of biomechanics to analyse kinematical movement parameters has increased in recent years, where for instance, Struzik *et al*. (2014:217) emphasised upper-limb symmetry in basketball through their research findings. They stated that players might be able to shoot more accurately from various locations and distances when making use of their kinematical analysis (Struzik *et al*., 2014:217). This was supported furthermore by a study done on wheelchair basketball players (Fay *et al*., 2013:716). It was observed that regardless of the handicap, the upper-limb movements contribute to the emergence of the especial skill known as free throw (Fay *et al*., 2013:716), suggesting that the shooting techniques, movement parameters and ball trajectories are modified to suite the altered movement parameters (Malone *et al*., 2002:701-710). Therefore, despite different biomechanical throwing kinematics from general able-bodied players, the parameterisation of chosen movements still underlies the free throw especial skill (Fay *et al*., 2013:716). The use of kinematical parameter analysis was encouraged by Breslin *et al*. (2012a:156), finding a distinct advantage for a constant practice group (though not for the variable group). This led them to investigate the movement paradigms applicable in confirming their original hypothesis on constant practice especial skill emergence (Breslin *et al*., 2012a:156). By focusing on the invariant features (relative timing, order of sequence, relative force) of a certain movement, the existence of a special, separate programme can either be supported or opposed (Keetch *et al*., 2008:734). For example, measuring relative timing would be invariant across other distances, with the measure distinguished between the free throw line and other distances (Keetch *et al*., 2008:734).

In conclusion, the results and analysis of a measurement such as relative timing could contrast the view of a specialised motor programme if the results proved to be constant at the foul line and other distances. This would support the existence of a single GMP, with only slight parameterisation differences being the major factor in memory representation (Keetch *et al*., 2008:734).

### 2.7 Summary.

The two influential motor-control theories (Adams's closed-loop theory – 1971; Schmidt's schema theory – 1975) give a detailed theoretical understanding of the basis of motor learning and -control (Magill, 1989:84). According to Schmidt (1975; 2003), an individual does not possess the ability to learn different movements or actions; rather, people develop the capability of performing skills throughout a variety of conditions, either previously experienced or never experienced (Keetch *et al*., 2008; Schmidt, 2003:367).

The argument that people rather learn to perform different skills than different movements suggests two advantages: firstly, an individual's memory is not constantly overloaded with storage requirements, and an individual has the luxury of flexibility in memory control when adapting to varying, unfamiliar conditions (Keetch *et al*., 2008:733; Schmidt, 2003:367).

In earlier literature (Keetch *et al*., 2005; Simons *et al*., 2009) the question of memory representation recruited in the emergence of an especial skill, such as in basketball and baseball, remains unanswered to some extent, leaving a 'research gap' on this aspect.

According to Schmidt's schema theory (1975:2003), the free throw shot could be represented by an exceptionally well-learned motor programme (Keetch *et al*., 2008:734). Training from the free throw line may create a separate GMP to represent the shots taken from locations other than the 4.57 m line (Keetch *et al*., 2008:734). If possible, this exceptionally well-trained GMP should be different from the GMP that governs shots from distances not used in training (Keetch *et al*., 2008:734). Keetch *et al*. (2008:734) stated that a convenient measure to differentiate GMPs is analysing the invariant features (i.e. relative timing) of each shot through kinematic analysis (i.e. biomechanics), similar to a previous study done on basketball (Breslin *et al*., 2010). This is especially important in analysing movement, as kinematics is inherently and in general defined '*as the study of mechanical laws relating to the movement or structure of living organisms*' (Oxford, 2011:111).

With reference to the above-mentioned literature, the importance of biomechanics and moreover kinematic analysis in movement and motor control research cannot be disregarded. Invariant features (Keetch *et al*., 2008; Magill, 2011; Schmidt, 1975) give researchers the basis for classifying a GMP governing a class of movements. Using kinematic recordings and - analysis, invariant features of the movements such as the basketball free throw describes the motor control parameters of these movements. Most importantly, studying invariant features of the movements will significantly broaden the understanding of motor control in general, giving plausible explanations for the existence of especial skills and the importance of practice conditions.

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# CHAPTER 3: ARTICLE 1[7]

**The different kinematic behavioural patterns of constant- and variable practice participants in the execution of the free throws (4.57 m) in basketball**

(Will be submitted to**: [8]The Journal of Sport Sciences)[9]**

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**ABSTRACT[10]**

The effect on shot proficiency and kinematic parameters of basketball free throws practiced under different practice conditions were examined. This was performed to determine the differences and its effect sizes in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between the basketball free throws (4.57 m) practiced in constant- and variable conditions Twenty (N=20) participants were randomly divided into constant (n=10) and variable (n=10) practice groups. Over five days, a pre-test, a retention-test and a three-day training intervention took place. Each participant shot free throws (100 shots per day) from five different distances (3.35 m, 3.96 m, 4.57 m, 5.18 m and 5.79 m – 20 shots per distance). In training, the constant group shot 100 shots from the 4.57 m line, while the variable group shot 20 shots from each of the five distances. Shots' relative timing were compared through a two-way repeated measure ANOVA; 2 (constant- and variable practice) x 2 (pre– and retention-tests) x 5 (five landmarks). No significant difference between the constant- and variable group emerged, however, a significant statistical difference between the pre-test and retention-test was noticed in both constant- and variable practice group. The

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[7] The word count of this article is 4219. Line numbering is not indicated by the 'Instructions for Authors' in the journal guidelines of Taylor & Francis online group.
[8] Author guidelines Appendix D
[9] Although Journal of Sport Sciences requires figures to be in separate files, figures are included in the text for the sake of the dissertation.
[10] For the sake of completeness, the abstract in the thesis exceeds the required 200 words with 23 words.

interaction effect was statistically insignificant in both groups. It is not confirmed that different practice conditions created different kinematic parameters.

**KEYWORDS:** kinematics, basketball free throw, especial skill, variability of practice, specificity of practice

## Introduction

Kinematics is useful to assess and analyse movements and parts thereof. In addition it is also used to determine and assess the influence of different descriptors of movements, such as different practice conditions. Magill (2011) further stated that it has become an important descriptor of performance in motor learning and -control. Kinematics, which is more generally associated with the term biomechanics, refers to *"the description of motion without regard to force or mass"* (Magill, 2011, p. 33). It commonly refers to displacement, velocity and acceleration of a certain object (Magill, 2011). The importance and use of biomechanics, more specifically kinematics, has been seen in overhead throwing sports such as netball (Hetherington et al., 2009) and basketball (Breslin et al., 2010; Breslin et al., 2012a; Keetch et al., 2005; Keetch et al., 2008; Miller & Bartlett, 1996) to describe and explain the mechanism in which the action is used in the different sports. Magill (2011) referred to it as performance production measures, hence its used to analyse and increase performance in certain skills, such as the basketball free throw.

The use of kinematics to assess movement parameters has been discussed and advised by researchers in the field of basketball, with Fay et al. (2013) stating that it would help to accurately train and select appropriate parameters needed for exceptional performance in wheelchair basketball. This was furthermore supported and emphasised by Struzik and co-authors (2014), who established, through kinematic analysis, the importance of upper-limb symmetry in the basketball shot technique.

Moreover, the basketball free throw was seen as a unique skill, after researchers (Keetch et al., 2005) found specifically the free throw basketball shot at the free throw line to outperform the other shots in the same class (i.e. shots taken at other non-trained distances). As a result, they evoked a new term and defined the free throw as an *especial skill*, which was defined as "*a skill within a more generalised class of actions that was distinguished from the rest of the class by its enhanced performance capabilities as a result of extensive amounts of practice*" (Keetch et al., 2005, p. 972). The shot accuracy was hypothesised to decrease as the throw distance from the basket increased; however superior non-linear shot proficiency at a distance of 4.57 m was noticed compared to six other distances (Keetch et al., 2005). Similar observations about the distinctive skills in terms of their superior performance capabilities within a more general class of skills, in their respective sports, were made in basketball (Breslin et al., 2010; Breslin et al., 2012a; Keetch et al., 2008), baseball (Simons et al., 2009) and archery studies (Czyz & Moss, 2016). Several theories exist as to what causes the emergence of these specific skills: the learned parameter hypothesis (Keetch et al., 2008) visual context hypothesis (Keetch et al., 2008), self-efficacy hypothesis (Simons et al., 2009), or specific motor programme hypothesis — also called especial generalised motor programme (eGMP) (Keetch et al., 2005, Czyz et al., 2013), though no definitive answer exists for the underlying cause of this emergence.

One method used to determine the mechanisms underlying the emergence of especial skills is kinematic analysis (Breslin et al., 2012b). Breslin et al. (2012a) established that free throws at a distance of 4.57 m share the same kinematic features (characteristics) as shots taken from other distances. It proved that especial skill (free throws at 4.57 m distance) is governed by the same generalized motor programme (GMP) as other shots taken from the non-trained distances. The term GMP that was used was initially introduced by Schmidt (1975) in his schema theory.

A GMP is seen as the fundamental motor programme that governs the entire class of actions, rather than only one specific movement. It would act as the support base for controlling a single action, because the GMP also stores the invariant features of the class (Magill, 2011). These invariant features are seen as similar shared characteristics stored for the movements within that more general class of actions and include relative force, relative time and order of sequence (Magill, 2011). Thus, by looking at these invariant features, one could compare different groups, such as constant (*massive amounts of practice and repetition to master a single task or skill* – Keetch et al., 2005:975) and variable (*practicing multiple variations of a single skill, movement or task* - Shoenfelt et al., 2002:1113) practice groups, and their effect on basketball free throw performance (Keetch et al., 2008; Magill, 2011). By using kinematic analysis to determine the above-mentioned invariant characteristics for each recorded free throw, researchers could determine whether or not the especial performance at the 4.57 m line was a direct result of specific-constant practice. Otherwise, they could establish if variability in practice could develop the GMP involved (i.e. schema theory – Schmidt, 1975) to such an extent that performance from several distances, not only the free throw line, increased as a result of training intervention. This emphasised the immense adaptability of the GMP associated with the basketball free throw to other distances or actions.

In light of the above-mentioned the objective of this study is to determine the differences and its effect sizes in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity, and angular acceleration) between the basketball free throws (4.57 m) developed in constant- and variable practice conditions, on testing days and after-intervention training days. This study is exploratory and it is difficult to advance a hypothesis based on previous studies, since to the best of the authors' knowledge, at the time of the study, there is none. However, for the purposes of the study, we hypothesised that the constant-practice group will show a statistically ($p < 0.05$) significant difference in kinematic parameters with a large effect size ($d > 0.8$) and kinematic behavioural patterns (i.e. peaks in flexion, angular velocity and angular acceleration) following the intervention session, as opposed to participants from the variable practice group, during the free throw (4.57 m).

Findings from the current study, will firstly aid future researchers in the field of especial skills and practice conditions under which to train these specific-, distinct skills. Secondly, the results achieved may enable coaches and players to use and adapt these findings in different tasks similar to the basketball free throw skill – such as darts, baseball pitching, archery and other possibilities, like kicking penalties and conversions in rugby where certain parameters are fixed and definite.

**Methods**

An experimental study design which was approved by the Health Research Ethics Committee of the North-West University (NWU-00117-17-A1) was used. Forms requesting informed consent were given to all potential participants. Detailed explanations of the experiment, the expectations of the research team were discussed in the consent form, including the procedures, outcomes, tests and risks included in the experiment. Participants could withdraw from the study at any time without any consequences.

***Participants***

A group of 20 male participants (age 21.8 ± 1.8 years) were randomly divided into two groups – a constant practice group (n = 10, 21.2 years ± 1.2) and a variable practice group (n = 10, 22.3 years ± 2.2). All participants had to confirm that they were fit and healthy, according to Fuller et al.'s (2007, p. 329) definition of "*any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity*."

No participants with prior experience (i.e. more than three months of organized training) in basketball, netball or korfball were allowed to participate. Participation in the respective sports was indicated in a personal questionnaire which they received with their informed consent forms; hence, all other sport codes and the number of months in practice associated with that sport had to be specified in the questionnaire. Constant practice group participants listed rugby as the sport in which they mostly took part, with half of the group indicating prior experience in rugby participation. Other sport codes listed were cricket, which had three participants, as well as korfball, squash, tennis, athletics and hockey, which had one participant each. The participants were involved in other sports for varying periods: rugby (133.2 months ± 81.2), cricket (106.7 months ± 88.8), squash (60 months), tennis (156 months), hockey (156 months) and athletics (108 months). Three participants had not been involved in any sports for more than three months, as defined earlier, and one participant listed korfball (three months) as a recreational sport.

In the variable group, six participants mentioned rugby as the sport in which they participated, cricket, hockey and athletics had two participants each, and one participant each listed road running and martial arts as the sport in which they took part. As in the constant group, no participant had prior experience in netball as per our definition and this was not included, but the estimated average time of participation for the other sports was listed as: rugby (165 months ± 62.3), athletics (90 months ± 42.4), hockey (90 months ± 42.4), cricket (82 months ± 58), martial arts (72 months) and road running (40 months). Two participants listed no prior experience or participation in any types of sport.

***Procedures***

After the recruitment process, each participant received an informed consent form and a personal information questionnaire two days before the experiment started. These forms were then collected on the first testing day by a member of the research team, identified by the lead researcher beforehand. Five consecutive days were allocated for the testing procedures, with the first and the last day specifically selected for pre- and retention-tests. Day two to four were training days, on which the intervention programme was implemented. Both the variable- and constant groups had to complete all five testing days comprising of 500 free throw shots from five different distances, which were equally divided. The distances used were: 3.35 m, 3.96 m, 4.57 m, 5.18 m and 5.79 m (Keetch et al., 2005). The day-to-day procedure over the five days is listed below:

- Day one: Personal information questionnaires and informed consent forms were collected before experimental procedures commenced. After a detailed explanation to the participants regarding the testing procedure, they had about ten minutes for warm-up and activation for the desired physical activity. After the warm-up phase, the research team instructed them to take 100 shots in a quasi-random order (20 shots from five distances each), with no more than two shots taken consecutively from the same distance. A kinematic recording of the first five shots taken by each participant was done, but only of shots taken from the free throw line (4.57 m).
- Day two to four: The intervention training programme was implemented over these three days, with a total of 300 shots being taken (100 shots per day). While the constant group took their 300 shots from only the 4.57 m line, the variable group took their 300 shots from all five distances (60 shots per distance), again in quasi-random order.
- Day five: Exactly the same procedure was followed for both groups as on day one. All 20 participants shot from all five different distances, 20 shots from each location, totalling 100 shots. A kinematic recording took place for the first five shots taken from the free throw line for both the constant- and the variable group.

***Kinematics***

For kinematical analysis, the procedure of Schneider and Schmidt (1995) and Breslin et al. (2010) was adapted, such as using similar reflective markers (Schneider & Schmidt, 1995) and kinematic landmarks (Breslin et al., 2010). Participants had to wear sleeveless shirts or no shirts for proper upper body analysis, and short trousers for lower body analysis. The players had to be barefoot as well during all five days, on both testing days and all three practice day procedures, to allow a proper view of the ankle and foot, and as a matter of consistency. Nine reflective markers were used for the purpose of analysis and put on the dominant side of the participant at the following locations: distal end of the fifth metatarsal of the toe, lateral malleolus of the ankle, lateral condyle of the femur and the greater trochanter of the femur. A further five landmarks were used on the upper extremity: distal end of the middle finger just below the nail, the hand about 1 cm below the middle finger, ulnar styloid of the wrist, lateral epicondyle of the humerus and the acromion process of the shoulder.

For the purpose of measurement and analysis, the beginning of the movement was when the elbow marker was at its lowest possible position, hence, where the participants prepared and generated momentum for the shot to follow. The end point of the movement was the point or moment where the basketball left the player's hand, hence, the moment when the middle finger marker was at its highest point, just before it lowered in the flicking movement of the hand as the basketball left it. Thus, for the starting- and end points, the lowest and highest points on the Y-axis of every movement were used for the elbow and middle finger markers respectively.
During the analysis, five different landmarks within each recording were examined, namely: negative peak velocity (- °/s) (landmark A), peaks in flexion (°) (landmark B), peak acceleration (°/$s^2$) (landmark C), peak velocity (°/s) (landmark D), negative peak acceleration (- °/$s^2$) (landmark E). To understand how the landmarks are seen in a recorded shot, Figure 1 explains each landmark as found in previous literature (Breslin et al., 2010, p. 58 – Figure 1).

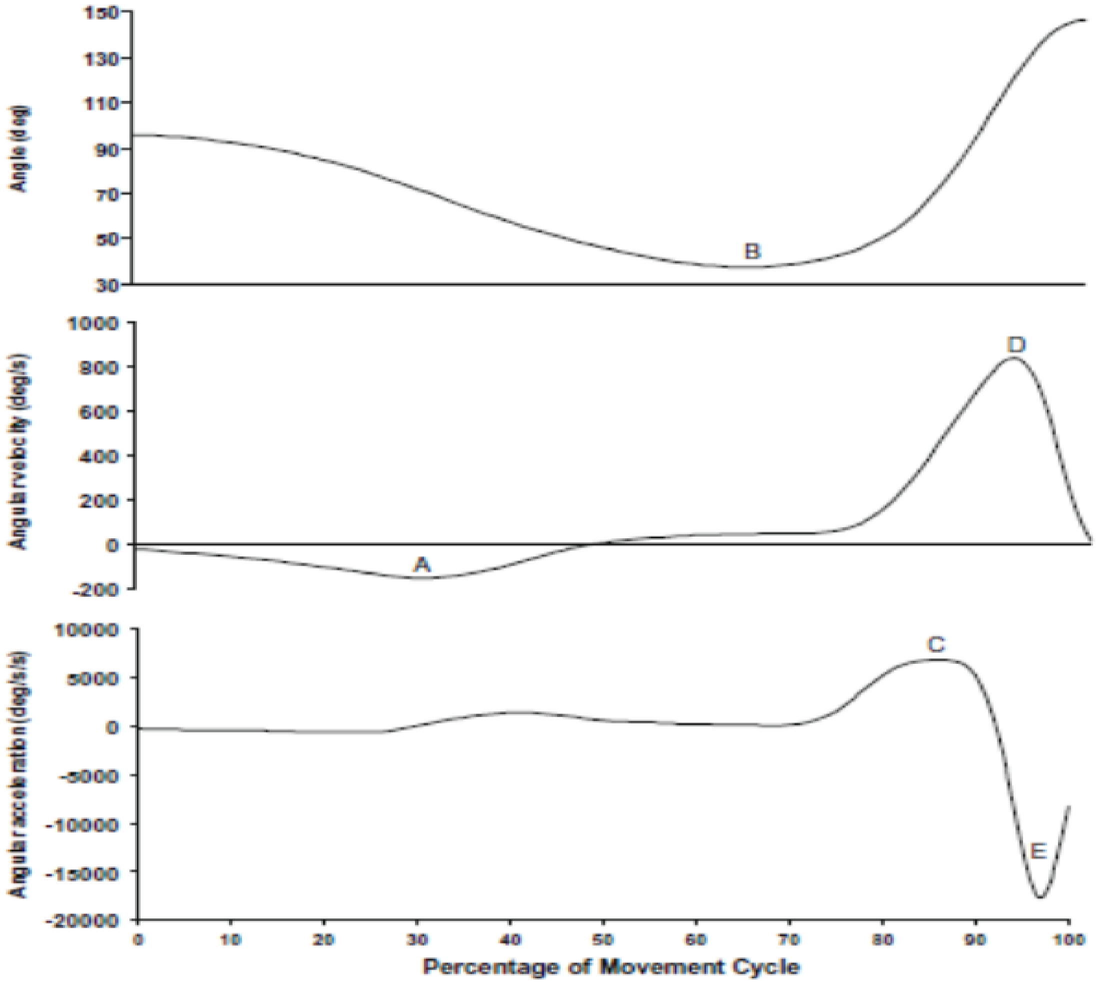


Figure 1. This is a recorded shot from a participant at the 4.57 m free throw line, as in Breslin et al.'s (2010, p. 58) experiment. The landmarks correspond to negative peak velocity, peak flexion, peak acceleration, peak velocity and negative peak acceleration respectively. This figure furthermore diagrammatically explains exemplar angle time, angular velocity time and angular acceleration time for each shot (Reprinted with permission from Breslin et al., 2010; Authors: Breslin, G. Hodges, N.J. Kennedy, R. Hanlon, M. Williams, A.M.; Breslin et al., 2010, p. 58 – figure 1.).

The reflective markers were applied by the same research personnel (i.e. co-supervisor and trained assistant) each time to ensure accuracy and consistency. Shots were captured with cameras (eight cameras - OQUS 3+, Qualisys AB, Sweden) and analysed with software (Qualisys Track Manager [QTM, Qualisys AB, Sweden] software). The camera resolution was set at 1280 x 1224 pixels, while the recording speed of the camera was set to 200 Hz. The calibration process for the cameras was done at the start of day one and day five before the first participant started, and often again throughout the day because of changing environmental factors such as sunlight reflections, which had an effect on the camera's recording proficiency. Before data capturing could be done by applying the Z-vertical, X-horizontal, and Y-medio-lateral coordination system, both static- and dynamic volume calibration of 24 $m^3$ (average residual 1.8 mm) was done. The calibration of the system enabled determination of the volume captured and minimised the lens distortion of each camera. Cameras were aligned in a circular manner to be able to pick up the reflective markers positioned on the participant effectively.

***Statistical Analysis***

For each variable, reported as a mean ± standard deviation (SD), descriptive statistics (averages, SD, minimum and maximum values, and non-parametric counterparts) were reported. Previous research (Breslin et al., 2012a) used a procedure in which the researchers used 300 practice trial shots over two days, and 200 shots in pre-and post-test, amounting to 500 shots taken over five days. Breslin et al*.'s* procedure (2012a) and their findings enabled us to use the same sample size, ensuring the use of a large data-set for analysis.

*Cohen's effect sizes* (*d*) ranges from small (0.2), medium (0.5) to large (0.8). Thus, even if a value is statistically significant, and if it does not have an effect size of at least 0.2, the effect of that significance is insignificant (Cohen, 1998).

*Kinematic analysis:* In order to analyse the kinematics of the basketball free throws, the relative timing as a percentage of overall movement time to reach five kinematic landmarks were calculated in the elbow joint (shoulder, humerus epicondyle and wrist markers): negative peak velocity (- °/s) (landmark A), peaks in flexion (°) (landmark B), peak acceleration ($°/s^2$) (landmark C), peak velocity (°/s) (landmark D), negative peak acceleration ($- °/s^2$) (landmark E) (Breslin et al., 2010; Schneider & Schmidt, 1995).

In the current study, an average (out of five shots for each participant) relative timing in the repeated measure two-way ANOVA: 2 (two levels: constant practice conditions and variable practice conditions) x 2 (two levels: pre- and retention-test) with practice conditions as a between-participants factor and the last factor as a within-participant repeated measure was used. Partial eta-squared (partial $\eta^2$) was calculated as a measure of effect size (small effect size = 0.01; medium effect size = 0.09; large effect size = 0.25). Five landmarks were used as dependant variables.

## Results

The homogeneity of variance was validated using Levene's test (see Table 1) (ANOVA assumption). Although some of the results were statistically significant (for landmarks A, B, C, D in the pre-test and D in the retention-test), after applying Bonferroni adjustment for multiple comparisons (ten comparisons, i.e. all of the statistical levels have to be divided by ten) all landmarks in both tests met the criteria (i.e. the significance level of tests' results was above 0.005). Therefore, both groups were found to be homogeneous.

Table 1. Levene's test for homogeneity of variances for the constant- and variable practice groups (effect: group).

| Test | Landmark | F | p | p after Bonferroni correction |
|---|---|---|---|---|
| Pre-Test | A | 5.59 | 0.029 | 0.294 |
| | B | 6.91 | 0.017 | 0.170 |
| | C | 9.87 | 0.005 | 0.056 |
| | D | 6.06 | 0.024 | 0.240 |
| | E | 3.27 | 0.086 | 0.868 |
| Retention-Test | A | 4.29 | 0.052 | 0.529 |
| | B | 2.41 | 0.137 | 1 |
| | C | 0.01 | 0.906 | 1 |
| | D | 5.15 | 0.035 | 0.356 |
| | E | 2.96 | 0.101 | 1 |

A – negative peak velocity; B – peak flexion; C – peak acceleration; D – peak velocity; E – negative peak acceleration. Statistical significance ("p"); significant difference between constant and variable practice groups ("F").

Mean values (%) and SDs for all landmarks for each group in pre-test and retention-test are shown in Table 2.

Table 2. Mean and SD of all landmarks for both groups in pre-test and retention-test.

| | Group | | A | B | C | D | E |
|---|---|---|---|---|---|---|---|
| Pre-test | CONSTANT | MEAN % (SD) | 85.37 (11.34) | 67.61 (23.35) | 71.87 (19.79) | 83.41 (8.89) | 83.82 (11.31) |
| | VARIABLE | MEAN % (SD) | 90.09 (6.64) | 82.20 (2.13) | 86.10 (8.40) | 90.63 (1.43) | 90.44 (6.19) |
| Retention-test | CONSTANT | MEAN % (SD) | 89.75 (10.09) | 81.59 (3.53) | 86.76 (6.47) | 89.45 (2.63) | 92.37 (1.38) |
| | VARIABLE | MEAN % (SD) | 92.09 (5.14) | 83.99 (2.42) | 86.29 (9.03) | 91.03 (1.48) | 89.93 (8.41) |

A – negative peak velocity; B – peak flexion; C – peak acceleration; D – peak velocity; E – negative peak acceleration.

In order to see how relative timing (landmarks) changed between the pre- and retention-test in both groups we drew two graphs (see Figure 2 – pre-test; and 3 – retention-test).

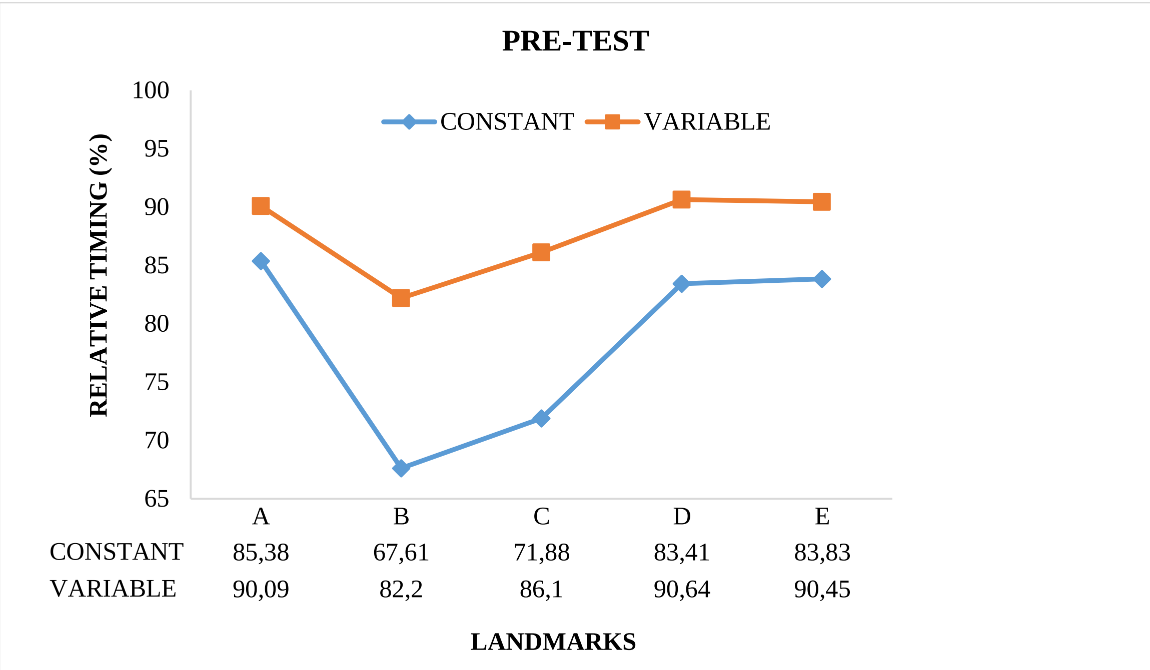


Figure 2. A graphical representation of how relative timing compared in the pre-test in the constant practice group to that of the variable practice group for the respective landmarks. (Constant practice group SD = 8.10; variable practice group SD = 3.69)

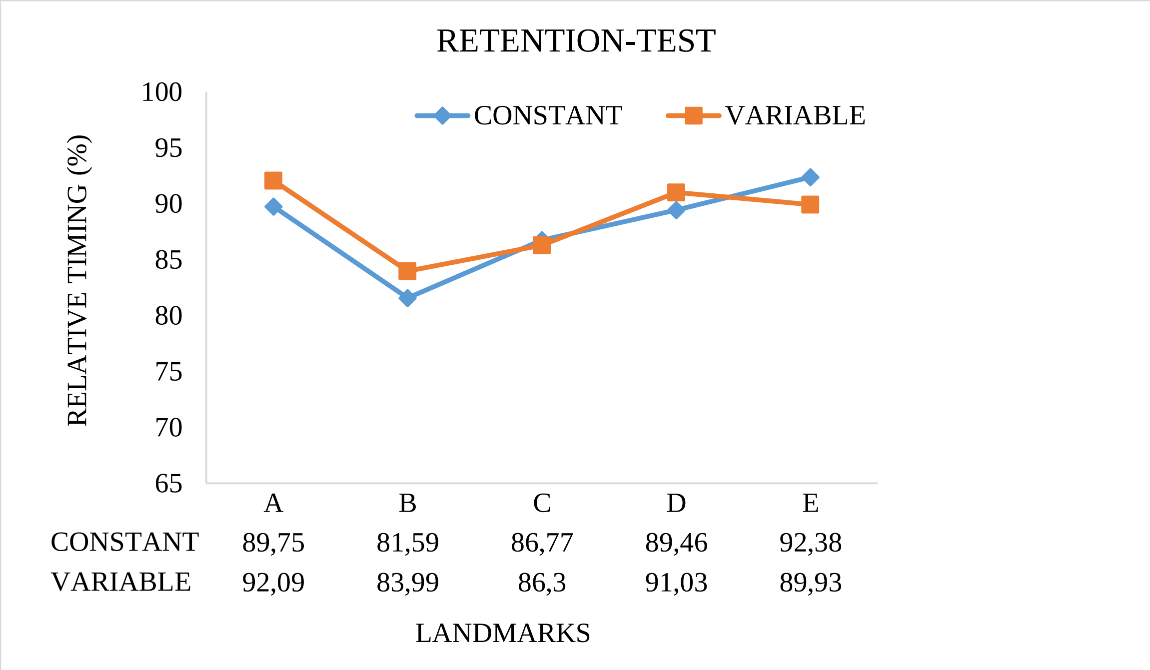


Figure 3. A graphical representation of how relative timing in the RETENTION-TEST compared in the constant practice group to that of the variable practice group for the respective landmarks. This change is attributed to the intervention training programme held over the three training days. (Constant practice group SD = 3.66; variable practice group SD = 3.05)

The biggest difference between the constant- and variable groups in the pre-test was observed in landmark B (peak flexion), with the variable group attaining the highest value of the two groups, while in the post-test the biggest difference between the two groups was observed in landmark E (negative peak acceleration), this time with the constant group having the higher relative timing percentage. The analysis of variances revealed that only one main effect was statistically significant ($p < 0.05$): test effect, the difference between the pre- and post-test results was statistically significant ($p < 0.001$), with a large size effect (partial $\eta^2 = 0.985$). The interaction (test and group) effect was insignificant (see Table 3. for details). Since only one main effect was significant and the interaction was not, no additional post hoc analyses were performed.

Table 3- Interaction effect and analysis of variance

| | F | Effect | p | Partial $\eta^2$ |
|---|---|---|---|---|
| Effect | | | | |
| Intercept | 3077.69 | 2 | **<u>0.000</u>** | 0.997 |
| Group effect | 2.56 | 2 | 0.107 | 0.232 |
| Test effect | 87.79 | 8 | **<u>0.000</u>** | 0.985 |
| Interaction effect (test * group) | 2.36 | 8 | 0.094 | 0.632 |

P – Statistical significance, partial $\eta^2$ – effect size, effect – large, medium or small effect according to partial eta value.

To determine the test effect differences for each landmark, a pair-wise t-tests for each landmark with the results from both groups (constant and variable) combined was performed. However, the additional analyses did not show any significant differences (Bonferroni adjustments were applied for multiple comparisons) – see Table 4 for details.

Table 4 – Statistically significance, practical effect sizes and the differences thereof between five landmarks (A-E) during the pre-test and retention-test.

| Landmark | Test | Mean | SD | t | Df | p | Confidence (-95%) | Confidence (+95%) | Cohen's d |
|---|---|---|---|---|---|---|---|---|---|
| A | PRE-TEST | 87.73 | 9.83 | -1.13 | 19 | 0.272 | -2.705 | 9.084 | 0.350 |
| | RETENTION-TEST | 90.92 | 8.31 | | | | | | |
| B | PRE-TEST | 74.91 | 18.59 | -1.88 | 19 | 0.074 | -0.857 | 16.627 | 0.590 |
| | RETENTION-TEST | 82.79 | 3.34 | | | | | | |
| C | PRE-TEST | 78.99 | 17.23 | -1.62 | 19 | 0.121 | -2.183 | 17.268 | 0.561 |
| | RETENTION-TEST | 86.53 | 8.07 | | | | | | |
| D | PRE-TEST | 87.02 | 7.52 | -1.94 | 19 | 0.067 | -0.250 | 6.691 | 0.579 |
| | RETENTION-TEST | 90.24 | 2.34 | | | | | | |
| E | PRE-TEST | 87.13 | 9.96 | -1.44 | 19 | 0.165 | -1.808 | 9.843 | 0.482 |
| | RETENTION-TEST | 91.15 | 6.31 | | | | | | |

A – negative peak velocity; B – peak flexion; C – peak acceleration; D – peak velocity; E – negative peak acceleration; p – statistical significance, d – effect size

Although there were statistically insignificant differences between landmarks for combined groups, medium effect sizes (d > 0.5) were found for three landmarks (B, C and D).

**Discussion**

The objective of this study was to determine the differences and its effect size in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between the basketball free throws (4.57 m) practiced in constant- and variable conditions on testing days and after-intervention training days. Selected kinematic parameters (peak flexion, peak acceleration, peak velocity, negative peak velocity and negative peak acceleration) were analysed. These measurements and analysis took place for both the constant- and variable practice groups. It is hypothesised that the constant practice group would show a significant difference in kinematic parameters and behavioural patterns both practically (measured by *effect size*) and statistically ($p < 0.05$). It is predicted that after a three-day training intervention programme a significant difference in the basketball free throw would be evident in the kinematical behavioural patterns of the elbow joint involved in the movement (peaks in flexion, angular acceleration, angular velocity).

Although some statistically significant differences were reported after analysis of the test effect (pre-test vs. retention-test), no significant ($p > 0.05$) differences between groups or in the interaction were found. The only significant difference in ANOVA analysis was between pre-test and retention-test results. However, further pairwise comparison showed that differences between landmarks were insignificant, although medium size effects were noted for three of the landmarks (Table 4). It is rational that differences between the pre-test and retention-test may occur. Considering that participants were unexperienced to basketball free throwing, one could expect radical changes in their shooting technique as practice progressed; regardless of the type of practice. Learning through generality and specificity would occur, which support earlier findings (Breslin et al., 2010). A different technique (before and after training interventions) is reflected in different kinematic characteristics. In addition, as the participants started their free throw practice, memory representations (the GMP that would govern free throw movements) were built, which is consistent with Schmidt's schema theory (Magill, 2011; Schmidt, 1975). Therefore, it is not surprising that relative timing of the landmarks changes as the practice thereof progresses, which may be a result of the development and creation of a memory representation, i.e. the GMP (Magill, 2011). Given that the interaction effect was insignificant, we cannot confirm the advanced hypothesis. The different practice conditions do not develop different kinematic movement patterns and different memory representation (GMP).

When comparing the current study findings with those of Breslin et al. (2012a), who used the original procedure that we replicated, both similarities and contradictions were found. Breslin et al. (2012a) used a post-test, whereas the current study implemented a retention-test, which was the sole difference in procedure – hence, the current study's participants experienced more permanent change and had to make use of memory representations of previous experiences, whereas they noted more immediate changes and effects. According to Magill (2011), post-tests and retention-tests differ in a number of ways. Firstly, as mentioned, the changes after the test are either more permanent (retention-test) compared to immediate and short term (post-test). Secondly, while the post-test is done immediately after the training intervention, with the training period and post-test not separated by any specific time, the retention-test is a test where memory allocation and storage by the players are done over a certain time period – hence, there in a break between training and testing. Lastly, and equally important, the retention test would test memory storage and memory recall (preferred type of motor learning) compared to post-test which would rather test the players immediate response to training. Furthermore, Breslin et al. (2012a) reported that the mode of practice rather than the amount of practice proved vital in especial skill emergence.

The current study's findings did not yield any significant data that could account for the same conclusion as that reached by Breslin et al. (2012a) who stated that practice creates a more refined memory representation of a single action within a general class of actions – implicating known theories of motor learning. However, Breslin et al. (2012a) also checked for the difference in kinematic parameters between trained and non-trained skills developed during constant practice, whereas we only checked for trained skills, however, under different conditions. However, in the current study, we could not disregard the possibility of constant and variable training causing especial skill emergence after no permanent changes were observed, Breslin et al. (2012a) confirmed it for the constant practice conditions. Their findings are in line with those of Schmidt (1975) and the predictions of his schema theory, which states that no single action within a more generalised class of actions can become more refined, but that the GMP governing that class can become more refined.

**Limitations and Recommendations**

The participants were entirely new to the concept of basketball. Thus, using a population with more experience may have yielded different results. With that being said, focusing more strongly on retention could be a future recommendation. That would involve doing a three-day training intervention similar to ours, but conducting different retention-tests on one, two and three days after the training intervention could shed light on practice type and retention advantages. Furthermore, one could manipulate the amount of practice on training days, hence, instead of 300 practice trials as in our current study and that of Breslin et al. (2012a), more training shots could be used to yield more convincing results.

Future research could focus on the type of practice and different visual contextual information, similar to that of Keetch et al. (2008). The main difference would be that instead of using only specified and constant training, one would apply both constant- and variable training and compare it over different angles and distances. This would allow researchers to investigate if their recall schema (Schmidt, 1975) and GMP adapt to the visual information as a result of practice modification.

With supportive results in training skills reported in the current study's findings for both constant- and variable practice, it is lastly recommend that the use and implementation of practice modification in more sport codes that share similar characteristics. Of the vast amount of sport skills known, these experimental studies have mainly been conducted on basketball, baseball (Simons et al., 2009), disabled sport (Fay et al., 2013) and archery (Czyz & Moss, 2016; Nabavinik et al., 2017). Research on kicking skills (i.e. soccer, rugby goal kick, National Football League (NFL) field goal) could yield endless transferable benefits from one sport to another.

**Conclusion**

Both practice conditions, i.e. variable and constant, develop the same kinematic pattern of basketball free throws. The analysis of relative timing of free throws confirms that practice in variable- and constant conditions develops the same GMP; therefore, the current study's findings did not support the notion that a separate motor programme is developed for the basketball free throw shot in either practice condition.

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**Disclosure statement**

No potential conflict of interest was reported by any of the authors.

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# CHAPTER 4: ARTICLE 2

## Especial skill effect in constant practice – study replication

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**ABSTRACT (120 words)**

The objective of this study is to determine the differences and its effect sizes in basketball free throws proficiency from the free throw distance (4.57 m) following training in constant- and variable practice. Twenty (n=20) participants were randomly assigned to either a constant- (n=10) or variable practice group (n=10). During the intervention period, the variable group replicated the pre– and retention-test procedure by shooting from five different distances, whereas the constant group completed all 300 shots from the free throw line. Shot proficiency was calculated by means of a four-point scoring system with linear regressions done at all distances to calculate predicted values. Neither group yielded significantly increased shot proficiency as predicted. No especial skill emergence as a result of the intervention programme was reported.

*Keywords*: practice conditions, especial skill, specificity of practice, variability of practice

### Introduction

The schema theory of Schmidt (1975) discusses practice conditions (constant vs. variable) and their effect on motor learning, which is based on the notion that no single action within a more general class of actions could be more refined. Constant practice refers to the specificity of practice mechanisms (Keetch et al., 2005; Magill, 2011), whereas variable practice could be

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regarded as “practicing multiple variations of a single action” (Breslin et al., 2012a, p. 154; Shoenfelt et al., 2002, p. 1113). It further conveys that practice creates a more generalisable motor programme, which governs the entire class of actions, known as a “generalised motor programme” (GMP) (Schmidt, 1975). With Schmidt’s (1975) schema theory consisting of two sections, GMP and recall schema, retention-tests’ focus on the ability of a player to recall and recognise the correct movement parameters. Certain skills are more refined within a more generalised class of actions, such as the basketball free throw, yielding better performance than expected at the 4.57 m line (Keetch et al., 2005). The emphasis shifted to certain uniqueness in skills, namely especial skills (Czyz & Moss, 2016; Czyz et al., 2015; Fay et al., 2013; Keetch et al., 2005; Simons et al., 2009). Especial skills could be described as a specific skill from a class of actions with superior performance parameters compared to the rest of the actions (Breslin et al., 2012a; Fay et al., 2013; Keetch et al., 2005).

The first study recorded on especial skills was on the basketball free throw (Keetch et al., 2005). The participants completed a free throw from seven different distances to test the shot proficiency compared to the shot taken from the free throw line (Keetch et al., 2005, p. 971). Keetch et al. (2005) predicted that as the distance from the basket increased, the accuracy and shot proficiency would decrease linearly as assumed by Schmidt, Zelaznik and Frank (1978) in their force-variability prediction model. However, a non-linear significantly ($p < 0.05$) better performance from the 4.57 m line was found compared to the other distances (Keetch et al., 2005, p. 972). The accuracy from the 4.57 m line was significantly higher than compared to the rest of the distances, showing an advantage at the free throw line above the other distances (Keetch et al., 2005, p. 972). Although a superior performance capability in some actions within the same general class of actions were noted, the question remained of what exactly caused an especial skill to arise in the basketball free throw (Breslin et al., 2012a).

Four hypotheses for especial skills emergence were formulated: firstly, the learned parameter hypothesis/parameter-specification hypothesis with massive amounts of practices the parameter specifications become more specialised in the basketball free throw (Keetch et al., 2005). Secondly, the visual-context hypothesis, -focusing on the visual cues present during the execution of the skill (Keetch et al., 2005). Thirdly, the specific-motor-programme hypothesis — addressing the principle that large amounts of practice lead to a new, separate motor programme being formed that governs the specific movement/especial skill (Keetch et al., 2005). Lastly, the self-efficacy/self-confidence hypothesis, stating that increased training on a certain skill will enhance the self-confidence and performance of that skill by the player (Simons et al., 2009). Keetch et al. (2005) were of the opinion that especial skills emerge as a result of massive amounts of practice. In contrast, Breslin et al. (2012a) believed that it might not be the massive amount of practice, but rather the type of practice, namely constant practice, that results in especial skills. In 2013, Czyz and colleagues (2013) computed a Bayesian model that was able to detect the especial skill effect at a very early stage, confirming that it is a practice condition itself (irrespective of the number of repetitions) rather than the amount of constant practice that leads to the development of especial skills.

Another group of researchers (Shoenfelt et al., 2002:1113) supported variable training, stating that players would acquire the ability through variable practice to adapt and react to unfamiliar situations (distance or angle changes from where the throw was taken). Referred by Schmidt (1975; 2003) as generalised training, scepticism about the use of variable practice in skills such as basketball free throws exist, though some studies emphasise the transfer ability from trained to untrained skills within the same class as important (Breslin et al., 2012a:154; Shea & Kohl, 1990:172). With no hypothesis to date completely rejected or accepted, a plausible cause for the emergence of especial skills was the type rather than the amount of practice (Breslin et al., 2012a, p. 154; Czyz et al., 2013, p. 139; Keetch et al., 2008, p. 735). In this regard, two studies reported no differences in shot proficiency between variable- and constant groups, though the especial skills effect was detected in the constant groups (Keetch et al., 2005; Breslin et al., 2012a, p. 156).

The inconclusive research and findings regarding the emergence of especial skills prompted us to replicate the study of Breslin et al. (2012a). In this instance the replicated model tested the especial skills using a retention-test and not a post-test as used by Breslin et al. (2012a). Retention-test refers to more permanent changes dependent on learning and memory, whereas post-test observes immediate changes and effects as a result of training intervention (Magill, 2011). Retention-tests are also done after an "empty" period where no training took place, which is not the case with post-test design (Magill, 2011). Hence it carries the potential to support the results of the original study empirically, either by clarifying issues raised by the original study, or extending its generalisability (Hani, 2009). The current study evaluated the shot proficiency of variable practice against that of constant practice. Our objective was to determine the differences and its effect sizes in shot proficiency from the free throw distance (4.57 m) as a result of an applied intervention programme, between and within variable- and constant practice groups. Based on results reported by Breslin et al. (2012a), we hypothesised that the intervention programme would yield significantly better shot proficiency from the free throw line (4.57 m) in the constant practice group ($p > 0.8$) than in the variable group ($p < 0.05$).

## Methods

The study followed an experimental study design and was approved by the North-West University's Ethical Committee (NWU-00117-17-A1). All the participants signed an informed consent form before commencement of the study. The procedures and outcomes of the daily activity and tests were also explained and thoroughly discussed with all participants.

## Participants

Twenty male university students (n = 20; age 21.8 ± 1.8 years) were randomly assigned to two groups, the constant practice (n = 10; age: 21.2 ± 1.2 y) and variable practice (n = 10; age: 22.3 ± 2.2 y) groups. Participants had to be injury-free and healthy at the time of testing. This could be defined as "*any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity*" (Fuller et al., 2007). No prior experience in basketball, netball or korfball was allowed. Prior experience was defined as any organised training (with a trainer/coach/instructor etc.) for more than three consecutive months, at least once a week, apart from activities during physical education classes or occasional, recreational play (without supervision). Participants stated their involvement in a maximum of three sport codes, where some players listed more than one sport code in which they had more than three months' experience, hence more than one sport was listed per participant if this was the case. The participants in each sport code were categorised into two groups based on the different conditions in which they practised, as stated in the questionnaires used in the study. The variable practice group consisted of six participants who played rugby as a sport. The following gives the estimated average time spent participating in different sports for the particular group: rugby (165 months ± 62.3), cricket (82 months ± 58), hockey (90 months ± 42.4), athletics (90 months ± 42.4), martial arts (72 months), road running (40 months). In the constant practice group, on the other hand, rugby was also the sport in which they participated most frequently (i.e. primary, secondary and tertiary options), with five of the total of ten listing rugby as a sport. As with the variable group, the time spent participating in these various sports are listed below: rugby (133.2 months ± 81.2), cricket (106.7 months ± 88.8), squash (60 months), tennis (156 months), recreational korfball (three months), hockey (156 months) and athletics (108 months). Two participants, one from each group, listed no prior experience or participation in any sport code.

## Procedures

The testing procedures took place over five consecutive days (Figure 1). The first and fifth days were designated to the pre-test and retention-test respectively. Testing procedures took place indoors in a laboratory controlled conditions, while day two to four were training days as part of an intervention programme. Both groups (constant and variable) participated in all five testing days. Over the five-day testing period, all the participants took 200 shots from five distances during the testing procedure (100 shots in both the pre-test and the retention-test), and during the training intervention, the variable group completed 300 shots from five distances and the constant group 300 shots from one distance (4.57m) (Keetch et al., 2005) totalling 500 shots over five days. Breslin et al. (2012a) presented a procedure in which they included 300 practice trial shots over two days, and 200 shots in the pre- and post-test. Each of our "warm-ups", comprised of individual static- and dynamic stretching of the upper- and lower limbs – five to ten minutes each time. The five-day procedure comprised the following:

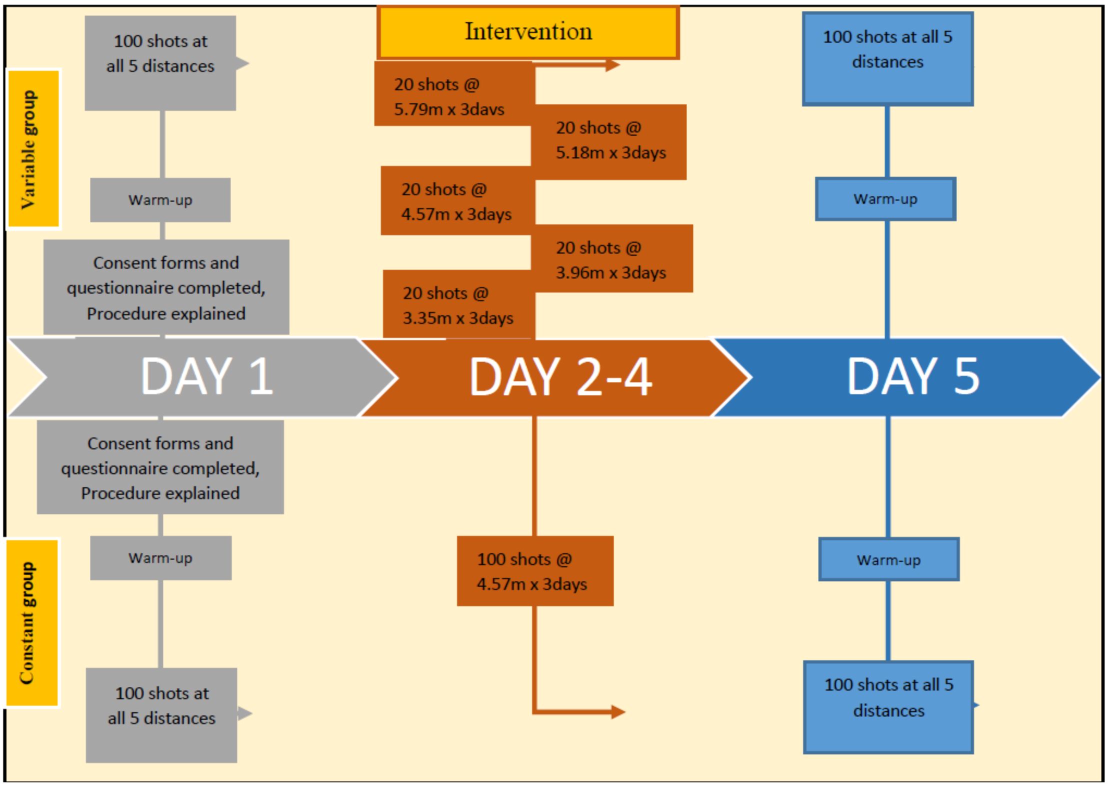


**FIGURE 1. Five-day testing procedure**

### Shot performance analysis

For the purpose of determining shot proficiency, a four-point scoring system (ranging from zero to three) was used (Keetch et al., 2005; Breslin et al., 2010). With three rewarded for a successful shot, without any hindrance (swish entrance into net). A score of two was awarded if the ball bounced once or came off the back-board and then entered the net, while a score of one was awarded if the ball bounced on the rim but did not enter. A complete miss was awarded a score of zero.

### Statistical analysis

For each variable, reported as a mean ± standard deviation (SD), descriptive statistics (averages, SD, minimum and maximum values, non-parametric counterparts) were calculated.

*Shot proficiency:* The four-point scoring system was used to calculate a success percentage at the different distance lines, comparing successful shots to unsuccessful shots for each participant. The scores for each participant's 20 shots at the five different distances were added and then an average percentage score of these 20 trial shots was calculated (pre- and retention-test), the maximum number of points that a participant could score is 60 (100%) (see Breslin et al., 2010; Keetch et al., 2005).

*Especial skill effect*: In order to detect especial skill effect, the same method applied in previous research is used (Keetch et al., 2005; Keetch et al., 2008; Breslin et al., 2012a; Breslin et al., 2012b; Czyz et al., 2013). Linear regression model was computed in order to fit each of the participant's shooting scores (shot proficiency scores). This was done separately for the pre- and the retention-test, allowing a clear estimate of a predicted accuracy value at the 4.57 m free throw line. The predicted values were compared to the actual values of the free throw line using paired sample *t*-tests. The linear regression equation was calculated by using the average scores (average shot proficiency scores) of all the participants at four different distances (except for the free throw distance, i.e. 4.57 m) (Keetch et al., 2005). These equations were then individually used to calculate the predicted shot score of each participant at the free throw line (4.57 m).

Using sample paired *t*-tests, actual values and predicted values were compared. These procedural inclusions to test for especial skills were adapted from the research studies of Breslin et al. (2012a) and Keetch et al. (2005). *Cohen's effect sizes* (*d*) ranges from small (0.2), medium (0.5) to large (0.8). Thus, even if a value is statistically significant, and if it does not have an effect size of at least 0.2, the effect of that significance is insignificant (Cohen, 1998).

$R^2$ tells us how much variability in the data is explained by the model and is useful when interpreting the strength of association between two random variables. In this case the $R^2$ values for all the regression models are very high (close to 1), indicating the adequacy of the models (Golberg & Cho, 2010). Thus, "R squared"; for example, in reference to Figure 5, $R^2 = 0.95$, which means that 95% of the variability in data is explained, hence, using the model we can describe the relationship between distance and shot proficiency. The other 5% of the variability in data has to be explained by variables other than the distance.

## Results

A linear regression was done for all the distances (except the free throw distance), for each participant and, based on the calculated individual regressions the predicted values at the free throw distance (4.57 m) was calculated. All individual predicted values were compared to the actual shot proficiency values of each individual, using *t*-tests. The predicted and actual values, as well as SD, for each experimental group are presented in Table 1.

**TABLE 1. Actual vs. predicted score at the free throw line in both the pre- and retention-test. Results for both the constant - and variable groups:**

| | | Pre-test | | Retention-test | |
|---|---|---|---|---|---|
| Group | Factor | Actual score at 4.57 m | Predicted score at 4.57 m | Actual score at 4.57 m | Predicted score at 4.57 m |
| Variable Group | Mean % (SD) | 36.5 (8.30) | 45.0 (6.00) | 50.0 (8.60) | 50.5 (3.70) |
| Constant Group | Mean % (SD) | 40.0 (9.20) | 47.6 (7.80) | 44.5 (5.90) | 50.1 (8.10) |

*SD = Standard deviation*

In reporting the results, as observed in Table 1, it is observed that for the variable group, a greater difference exist between the actual score and the predicted score of the pre-test, however, in the constant group, the greatest difference was observed in both the pre- and retention-test. Hence, these participants underperformed well below what we predicted based on the models of regression in all figures (Figure 2, 3 and 5) except Figure 4, where the prediction from the free throw line was met by very close actual performance from the variable group. Furthermore, improvements in both the constant- and variable group were seen from pre- to retention-test, with the variable group showing the greatest improvement (Table 1).

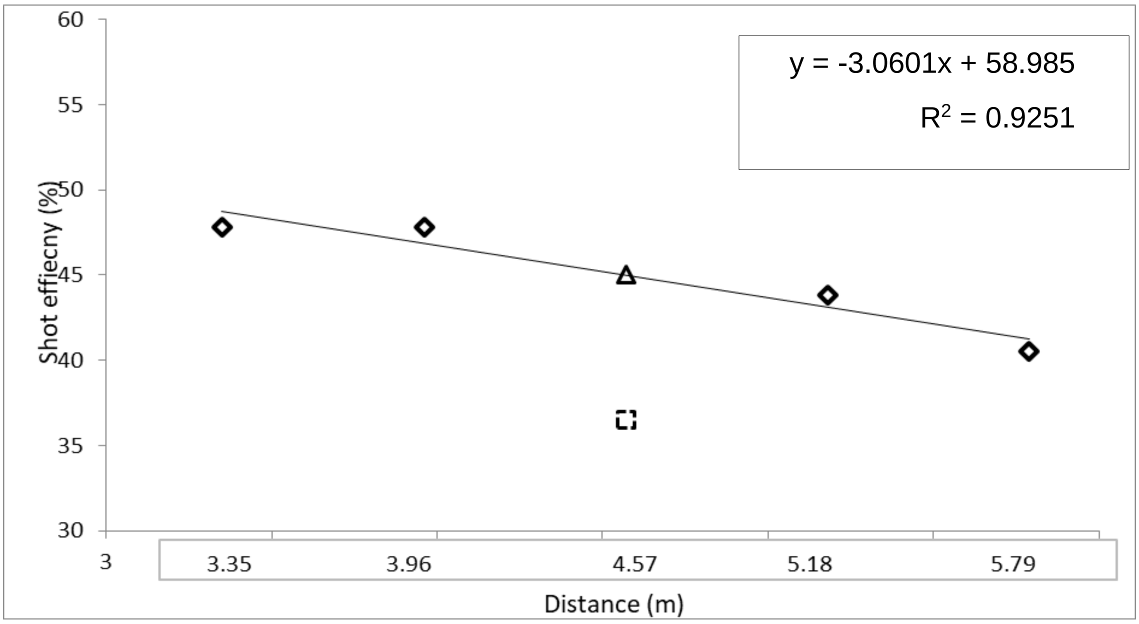


**FIGURE 2.** Regression for the pre-test of the variable group

*Line- predicted regression performance line for shots taken; rhombus – actual performance at each distance; triangle – expected performance at 4.57 m free throw line; square – actual performance at 4.57 m line. $R^2$ – effect size.*

During the pre-test (Figure 2), a 45% proficiency for the variable group was expected, however, the actual shot proficiency was 35% at the free throw line, much lower than predicted. Furthermore, two distance shots (3.96 m and 5.18 m) scored higher than predicted, whereas the closest and furthest distance was slightly lower than predicted. Similar results are seen in Figure 3. During the pre-test, a 45-50% shot proficiency at the free throw distance was expected for the constant practice group, however, a slightly lower than 40% shot proficiency was found. The observations at the other distances during the pre-test of the constant group (Figure 3) were similar to that of Figure 2 (variable pre-test).

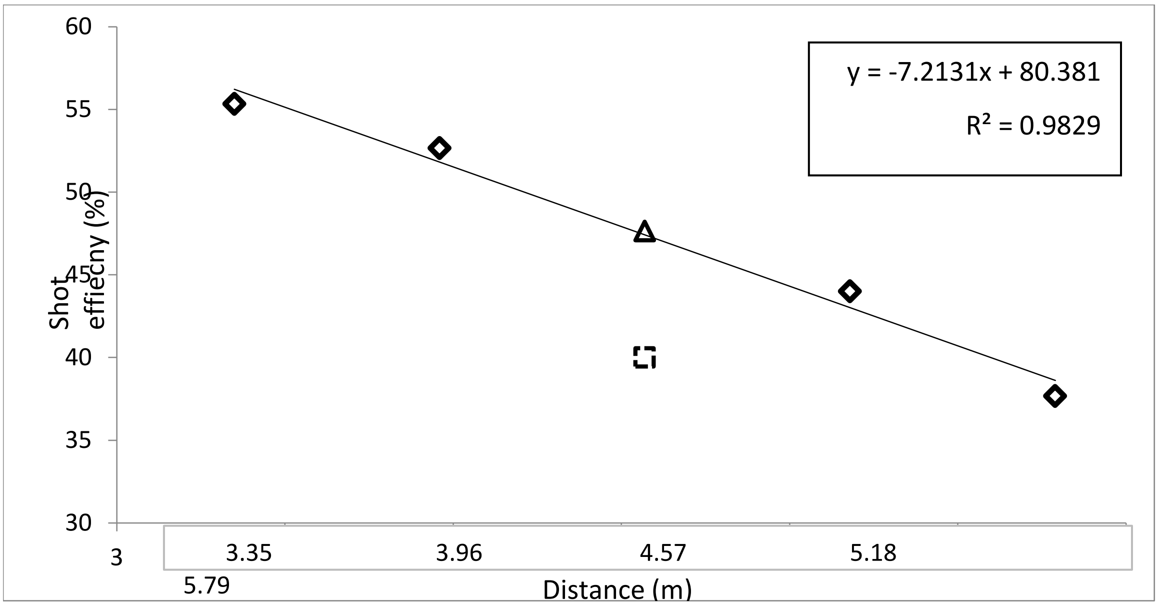


**FIGURE 3.** Regression for the pre-test of the constant group

*Line- predicted regression performance line for shots taken; rhombus – actual performance at each distance; triangle – expected performance at 4.57 m free throw line; square – actual performance at 4.57 m line.* $R^2$ *– effect size*

The retention-test for the variable group (Figure 4) showed actual results much closer to the expected results than those observed in the pre-tests. The actual performance at the free throw line was slightly lower than expected, but as observed, both were in very close proximity to 50% shot proficiency. The closest and furthest distance had higher proficiencies than expected, and the other two distances the opposite, as clearly shown in Figure 4

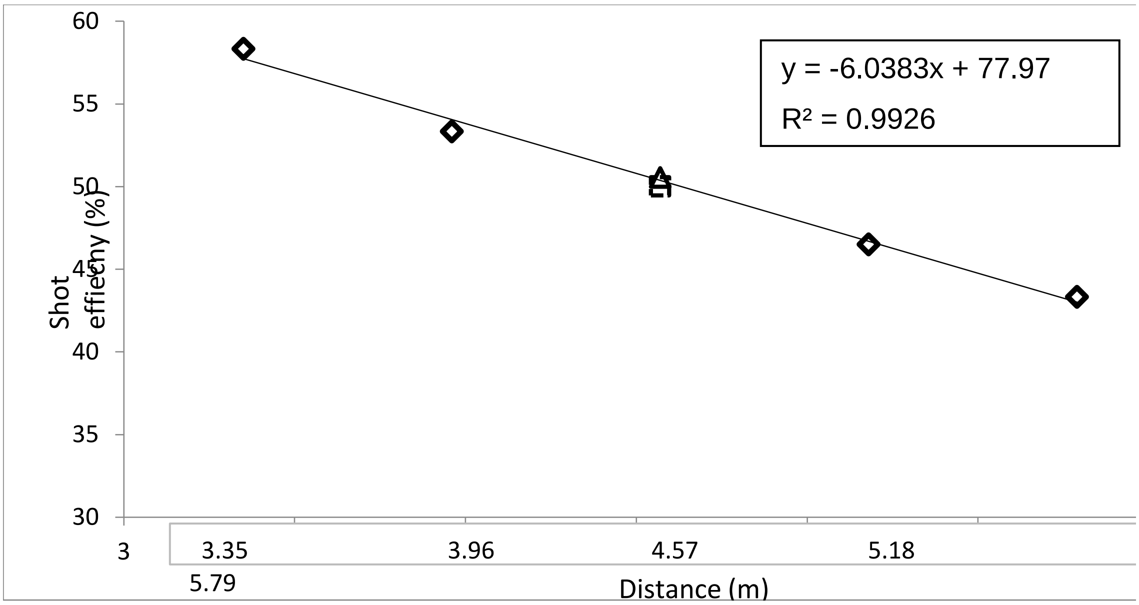


**FIGURE 4.** Regression for the retention-test of the variable group

*Line- predicted regression performance line for shots taken; rhombus – actual performance at each distance; triangle – expected performance at 4.57 m free throw line; square – actual performance at 4.57 m line.* $R^2$ *– effect size.*

Similar results were observed following the retention-test (Figure 5) compared to the pre-test (Figure 3) of the constant practice group. It is predicted that the constant practice group would at least have a 50% accuracy or shot success at the free throw line. However, as observed in "Figure 5", the performance was about 45% at the 4.57 m line. Less than expected results are also observed in accuracy at the first-, second- and fifth distanced shots (Figure 5). Only the 5.18 m distance had higher accuracy than the expected values (Figure 5).

Although a clear visual description of the pre – and retention-tests for both the constant and variable practice groups can be seen in "Figure 2 to Figure 5", Table 2 gives a clear numerical explanation of the data on page 80.

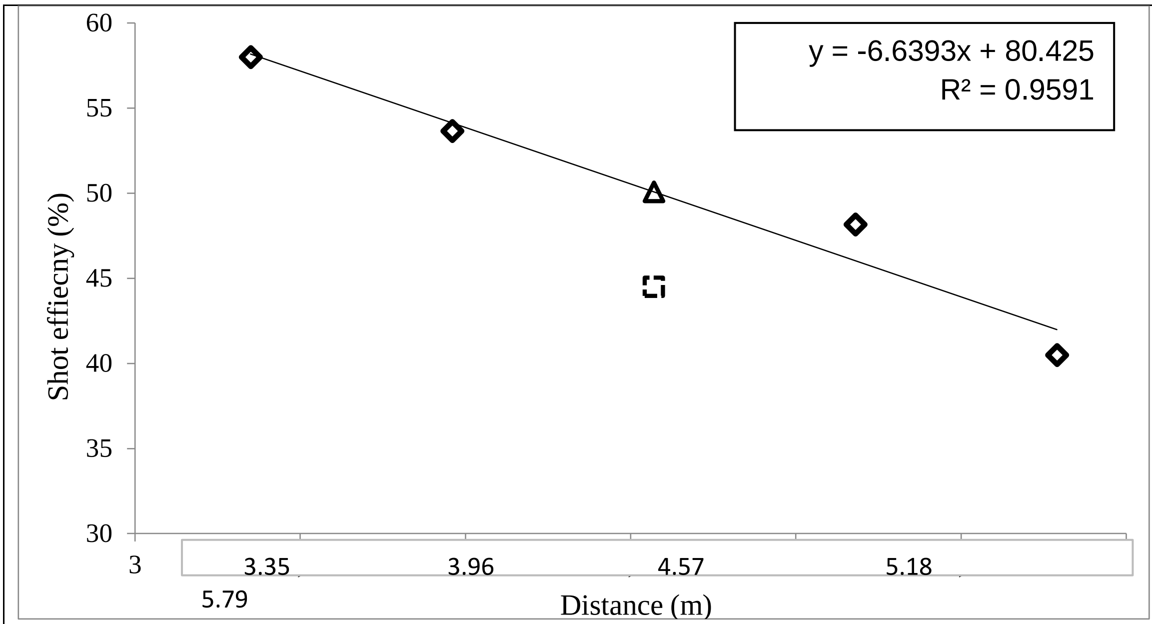


**FIGURE 5**. Regression for the retention-test of the constant group

*Line- predicted regression performance line for shots taken; rhombus – actual performance at each distance; triangle – expected performance at 4.57 m free throw line; square – actual performance at 4.57 m line. $R^2$ – effect size.*

Given the high values of $R^2$ in all computed linear regressions (ranging from 0.9251 – 0.982 for pre-test and 0.9591 – 0.9926 for retention-test) it may be assumed that the models fitted our data well and was adequate for calculating expected values. By taking this into consideration, based on the model used, 95% of variability in data was explained in Figure 5 (constant group retention-test), 99% in Figure 4 (variable group retention-test), 98% in Figure 3 (constant group pre-test) and 92% in Figure 2 (variable group pre-test). This means that of all the R-squared values, Figure 2 had the highest amount of data that needed to be explained by variables other than distance.

The results of the *t*-tests are presented in Table 2. The largest effect size is noticed in the pre-test of the variable practice group, whereas the smallest effect size was noticed in the retention-test of the variable practice group. This was also the biggest difference in effect size between two groups, indicating a rather large difference in effect after the training intervention. The constant practice group, in contrast, had a much smaller difference in effect size, but more importantly, the retention-test done after the training intervention, had the larger effect size of the two tests.

**TABLE 2:** Results from the t-test used to compare actual values with predicted values

| GROUP | TEST | Score | Mean | SD | N | t | df | p | Cohen's d | Confidence -95,00% | Confidence 95,00% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Pre-test | Actual | 36,5 | 8,331 | 10 | -4,571 | 9 | **0,001** | **1.020** | -12,706 | -4,293 |
| | | Predicted | 45 | 5,961 | | | | | | | |
| | Retention | Actual | 50 | 8,571 | 10 | -0,215 | 9 | 0,835 | 0.063 | -6,238 | 5,156 |
| | | Predicted | 50,541 | 3,727 | | | | | | | |
| Constant | Pre-test | Actual | 40 | 9,196 | 10 | -2,842 | 9 | **0,019** | **0.831** | -13,725 | -1,559 |
| | | Predicted | 47,642 | 7,812 | | | | | | | |
| | Retention | Actual | 44,5 | 5,882 | 10 | -3,154 | 9 | **0,012** | **0.949** | -9,587 | -1,579 |
| | | Predicted | 50,083 | 8,102 | | | | | | | |

*SD = Standard deviation; t= test statistic; df = the degrees of freedom of the test and p = the significance of the test; d = Cohen's effect size (0.2 = small; 0.5 = medium; 0.8 = large).*

## Discussion

The objective of this study was to determine the differences and its effect sizes (Cohen's *d*) between actual- and predicted shot proficiencies from the free throw distance (4.57 m) as a result of an applied intervention programme. A significant difference ($p < 0.05$) and a large effect size ($d > 0.8$) is found between the actual- and predicted means for the constant group in both the pre- ($p = 0.019$; $d = 0.831$) - and retention-tests ($p = 0.012$; $d = 0.949$), as well as for the pre-test of the variable group ($p = 0.01$; $d = 1.020$), however, no significant difference between the actual- and predicted means was seen for the variable group following the retention-test ($p = 0.835$) and it only had a small effect size ($d = 0.063$).

As it can be seen in the figures above , the actual shot efficiencies point were below regression lines in both groups for both tests. Thus, no especial skill effect was noticed in pre- or retention-tests regardless of practice conditions, as the especial skill effect refers to over performance. We performed *t*-tests in order to test if the actual values were different from the predicted values as the testing was not performed to confirm Breslin et al.'s (2012a) findings, but to see if the differences between actual- and predicted values were statistically significant. Dissimilar to Breslin et al. (2012a), the actual values were below the predicted score. The only statistical difference and large effect size was noted in the variable group's pre-test ($p = 0.001$, $d = 1.020$), before the application of the three-day intervention programme, thus the predicted values were not significantly different from the actual values in the retention-tests. Especial skills were not recreated in the participants in either group and shot performance at 4.57 m could be approximated with a linear regression computed on the basis of shot proficiencies at other distances.

The main observation that we attribute to the difference between our findings and those of Breslin et al. (2012a) is the mode of testing after the training intervention. Whereas Breslin et al.

(2012a) used a post-test, we actually implemented a retention-test. The post-test is a test done immediately after the training intervention, with no days or specific time separating the intervention and post-test. In contrast, the retention-test is a test done after players have been given a certain time to store the movement parameters. Furthermore, retention-tests could be regarded as the preferred type of test assessing learning, especially motor learning, as retention-tests focus on memory storage and recall mechanisms, and post-tests could be seen as tests focusing more on memory response and immediate practice/training effects (Magill, 2011). Therefore, using retention-tests would provide evidence on the transfer of skills retention after an "empty period" in which training did not take place; in this case, the time taken after our last training day in the intervention, to the time when the players were tested again in the retention-test. No separate motor programme was formed during any form of training used (constant or variable), and the same generalized motor programme (GMP) governed the basketball free throw after both forms of training. Training modification did not cause especial skill emergence at the free throw line. In conclusion, our findings did not confirm our hypothesis stated in the introduction that constant practice would yield better shot proficiency at the free throw line and also failed to provide proof that one form of training would cause especial skill emergence.

## Limitation and recommendations

Unlike Breslin et al.'s (2012a) study, in which a post-test was used in order determine the effect of constant practice conditions in development of especial skill, a retention-test which is a more appropriate in measuring learning effects was implemented. The results of the retention-test did not show the over performance in shot accuracy at the free throw distance, i.e. it did not detect especial skill effect as compared to what was reported by Breslin et al.'s (2012a) in the post-test.

Although the difference between actual- and predicted scores at the free throw line were not significant following an applied intervention programme, we could not completely rule out the possibility that either constant- or variable practice had the potential to evoke especial skill emergence. Future research should focus on the player's ability for memory or skill retention after the implementation of constant- and variable practice.

A much broader spectrum of sport skills should be considered as well. Up to now, the main focus has been on basketball free throws (Keetch et al., 2005; Keetch et al., 2008; Breslin et al., 2010; Breslin et al., 2012a; Breslin et al., 2012b; Czyz et al., 2013; Czyz et al., 2015), with a few exception seen, with baseball (Simons et al., 2009), wheelchair basketball (Fay et al., 2013) and archery (Czyz & Moss, 2016) among others. Focus on skills with similar GMPs should be considered, such as a fixed kicking mechanism or movement parameter (soccer penalty kick, rugby place kick, American Football / National Football League [NFL] field goal).

## Conclusion

In neither the constant- nor variable practice conditions was the especial skill effect noticed. With no clear indication of what causes especial skill emergence, one cannot completely disregard the potential of practice modification as the underlying reason for especial skill emergence.

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# CHAPTER 5
# SUMMARY, CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

## 5.1. Summary

The purpose of this study was, firstly, to compare the kinematic behavioural patterns and parameters between constant- and variable practice conditions groups during the execution of a basketball free throw at the 4.57 m free throw line. We wanted to determine the differences and its effect sizes in kinematic behavioural patterns and kinematic parameters (i.e. peaks in flexion, angular velocity and angular acceleration) between the basketball free throws (4.57 m) practiced in constant- and variable conditions, on testing days and after-intervention training days. In addition we also wanted to determine the, differences and its effect sizes in shot proficiency from the free throw distance (4.57 m) as a result of an applied intervention programme, between and within constant- and variable practice conditions groups.

Chapter 1 provided a brief overview of the problem probed in the research questions, as well as the research question itself, the objectives of our study and lastly our hypothesis. While taking into account the research question, it was clear that a pre-test and retention-test design would be the most accurate and effective method to test our hypothesis. From this chapter it was clear that further research and another approach was needed in order to determine the cause and reason for especial skill emergence at the free throw line (4.57 m). While previous researchers looked at the effects of massive amounts of practice, recent literature focused on the type of practice used to train a skill rather than the amount of time spent in mastering the specific skill. In order to predict the outcome, the current study had to be an exploratory study. However, our initial hypothesis stated that the constant practice group would show a statistically significant ($p < 0.05$) difference with a large effect size (partial eta squared, R squared) after the applied training intervention for both the kinematical parameters and shot proficiency, compared to that of the variable group.

Chapter 2 comprised of a literature review, titled: *Kinematic analysis and especial skills in constant- and variable practice conditions in overhand throwing actions*. The start of this chapter provided a brief overview of basketball shots and the free throw (main focus), as well as the aspects that make this shot unique in the sport. This led to a discussion on the modes through which skills such as the basketball free throw have been trained over time, and the effects of training methods on the performance of these skills. Literature on constant- and variable practice conditions, including their respective characteristics, previous use and effectiveness reported in previous studies remains the focus in the literature review. The findings of recent literature regarding the practice types led us to provide the reader with a basis to understand how the players responded to the different types of training used. It presented a detailed introduction and led to the term generalised motor programme (GMP), which was described as a motor programme that governs and controls skills within the same general class of actions.

Simultaneously with the effort to understand how training had an effect on the performance or execution of certain skills in terms of motor programmes, another part focused on the main purpose of our study, namely especial skills. The term was ascribed to a skill that had a distinct uniqueness to it within a more general class of actions (i.e. basketball free throw shots from all over the court), and it was also described as a shot that was special in view of the amounts of practice spent on it. Keetch *et al.*'s (2005) research was a major focus point in our literature review, whereby we attempted to give the reader a clear understanding of especial skill, as the author and her team are widely known as the first to have done research on especial skills. Moreover, they also focused on the basketball free throw, as was the case in this research study.

In their experiment they predicted that the free throw shot performance from five different distances would conform to the force variability principle (i.e. as the distance from the basket increases, the accuracy or shots decreases). However, this was not what they found, as the regular free throw line (4.57 m) proved to be the distance where players had a much greater ($p < 0.05$) success rate than expected, and they stated that the uniqueness of the basketball free throw at this distance was a result of the above-mentioned massive amounts of practice. Similar results were seen in literature (Simons *et al*., 2009) regarding the baseball pitch, wheelchair basketball, the basketball free throw, and more recently archery.

Significant research and theories regarding the emergence of especial skills and the cause thereof have been reported in previous literature studies (Keetch *et al*., 2005; Simons *et al*., 2009). We presented four major hypotheses regarding the especial skill emergence: the learned parameter hypothesis (i.e. massive amounts of practice); the visual contextual hypothesis (i.e. the importance of visual cues in training skills); the specific-motor-programme hypothesis (i.e. after massive amounts of practice, especial skills develop their own distinctive motor programme); and lastly, the self-efficacy hypothesis (i.e. extensive amounts of training would create more self-confidence in the players and as a result facilitate better performance). However, with no ultimate *explanation*, no final verdict on any one of the known theories could be given, which led to our discussion of the Schema theory, as one of the most profound theories in the understanding of motor learning and control. These theories revolving around the emergence of the especial skills led to the term GMP, which was described as a motor programme that governed and controlled skills within the same general class of actions. With stronger focus emerging on motor learning towards the end of this chapter, and to determine whether or not the type of practice could have an effect on especial skill emergence, greater focus was placed on the research of Breslin *et al*. (2012a). They had already established that massive amounts of practice were not needed to evoke the especial skill, but a mere 300 shots, which supported our pursuit of training type rather than training time.

The fundamental design of a GMP was that it not only contained the mode to control a certain skill, but also the ability to store similar shared characteristics of skills within the same class of actions — known as invariant features. By focusing on relative time, relative force and order of sequence, we would be able to distinguish between constant- and variable practice groups, taking into account the start and end time of the movements, hence looking at their respective kinematic parameters. For us to be able to examine peak angle, angular velocity and angular acceleration as kinematic parameters, we had to record the player's shots and analyse these shots to measure each of the parameters in the different shots.

Therefore, this chapter ended by focussing on a biomechanical analysis (more specifically, kinematic analysis) used in previous literature. To measure and analyse the invariant features of each participant in our study, we looked at previous findings regarding the basketball free throw, among others. The chapter gives a detailed overview of kinematics, but more importantly, of the reasons why we decided to use it as a tool to test our hypotheses. By looking at invariant features, we could support or contradict the existence of a single GMP that controls a general class of actions, or see if a separate motor programme exists for especial skills. Breslin *et al*. (2010) had done a similar experiment to ours, and therefore allowed us to replicate, adjust and improve their methods.

In Chapter 3, an article is prepared in accordance with the guidelines of the *Journal of Sport Sciences*, titled "*The different kinematic behavioural patterns of constant and variable practice participants in the execution of the free throw (4.57 m) in basketball*". The purpose of this article was to compare and distinguish between the kinematic parameters in the constant- and variable practice groups during the basketball free throw. We predicted that a statistically significant difference ($p < 0.05$) and a large effect size would be evident when comparing the constant practice group to the variable group, hence that constant practice would prove the better practice condition to train under.

In contrast, our findings showed that neither a large effect size ($\eta^2 = 0.26$) nor any statistically significant ($p > 0.05$) difference was detected in any of the two groups following the three-day intervention training programme. Even though we predicted that the difference in effect would be in strong support of training skills under constant conditions, the effect of our results did not prove clearly that this was the case. Using the effect size through partial eta squared values ($\eta^2$), our results could be compared to other studies with the same variables (Czyz *et al*., 2015), which in turn would make the research more credible and sound, since $\eta^2$ allows this comparison even if different covariates are included in the different studies. Moreover, we did find a significant difference between the pre–test and retention-test for both the constant- and variable practice groups. Whereas our predictions indicated that two different GMPs would be formed under the respective practice conditions, and that one would be better than the other, our results only proved that two different GMPs formed; however, these were different in features, each with its own advantages and disadvantages.

The second research objective was posed in Chapter 4, with the research title "*Especial skill effect in constant practice — study replication*". This article was compiled in accordance with the guidelines of the *Journal of Motor Behavior*. The purpose of this article was to compare the shot proficiency for the constant- and variable groups from the free throw line, after the application of an intervention training programme. We hypothesised that the constant practice group would provide a large effect size ($d > 0.8$) and statistically significant ($p < 0.05$) difference in shot accuracy from the free throw line following the training programme.
Our findings did not confirm our hypothesis. We did not find any significant difference in shot proficiency between the constant- and variable practice groups, even though some differences were observed between pre-tests and retention-tests. Furthermore, our findings did not indicate support for practice conditions as a cause for especial skill emergence in neither the constant group nor variable group. Thus, we found that the way in which practice conditions in constant- or variable groups were organised in our experiment did not cause especial skill emergence and we could therefore not support or omit for that matter practice conditions as a probable cause of especial skill emergence.

Therefore, we could not confirm that the type of practice used in training the basketball free throw from the 4.57 m line would cause especial skill emergence. One of the main reasons for this is that, unlike Breslin *et al*. (2012a), we did a retention-test rather than a post-test. A one-day retention-test was done after the three-day training intervention, whereas Breslin *et al*. (2012a) immediately did a post-test after their participants did their training. Commonly, big differences are found between post–test and retention-test results. This could have been due to the immediate post-test they performed after their training. The transfer effects and change in memory from training to creating the especial skill were more permanent than in our study, which used a retention-test. Magill (2011) noted in his literature regarding motor learning that the retention-test procedure is considered a more reliable measure of learning, thus supporting it rather than the post-test design.

In summary, we looked for a probable cause of the basketball free throw’s unique and especial status among the trained and untrained variations of the skill, hence evaluating the proficiency of these variations under different practice conditions. The distinct advantage that the free throw shot from the 4.57 m line enjoys both supports and contradicts well-known theories that a specific skill could be more refined than another skill within a general class of similar skills. Kinematic recordings and analysis of the free throw shot were evaluated for this reason, albeit from different distances, in an attempt to determine what exactly caused the uniqueness at the 4.57 m line, and if there was something specific associated with the free throw shot action that distinguished it from the rest of the shots.

Kinematic recordings were also evaluated for a more specific reason — to focus on the invariant features (similar characteristics shared by similar skills), which allowed us to look at features such as relative timing patterns at different distances, again allowing us to see if there were major differences at the free throw distance compared to the other adjacent distances.

The aim of our experiment was not to determine whether the amount of practice could account for skills to gain especial status. However, if we compared our findings to those reported in previous literature (Keetch *et al*., 2005), which suggested that massive amounts of practice were needed for especial skill emergence, we could contradict those findings. This was because we found that 300 trials, or rather up to this number of practice shots, were not enough to evoke especial performance, as noted in our study. Moreover, in comparing the amounts of practice with practice conditions, there is evidence in favour of both. However, no clear answer could be given as to what causes especial emergence, and furthermore, what governed these skills when practised by players.

We reported that the way in which we implemented the different training methods could not clearly be given as a cause for especial skill emergence, neither supporting constant- or variable practice as a means to evoke it, nor completely discarding it as a cause of the distinct advantage seen at the free throw line. There was, however, a clear indication that overall performance in both practice groups we tested showed increased improved from not only the free throw line, but also from the adjacent distances. This definitely shows that massive amounts of practice are not necessarily needed to improve the free throw shot; however, it is unclear whether such practice is needed to evoke the especial skill that is the 4.57 m line free throw shot. We could deem kinematic analysis a probable solution to deciding the especial skill debate in future, as it allowed us to look more closely at the inherent features of the shot and the effect of training on it.

## 5.2. Conclusions

In accordance with our initial hypotheses set out in Chapter 1, the following conclusions were reached:

**Hypothesis 1**: *The constant practice group will show a significant difference (p < 0.05) with a large effect size in kinematic parameters and kinematic behavioural patterns (i.e. peaks in flexion, angular velocity and angular acceleration) of the basketball free throw following the intervention session, as opposed to those in the variable practice group.*

- No difference in kinematic parameters between the constant- and variable groups were reported, and analysis of one of the invariant features, i.e. relative time, did not support the theory of a separate motor programme being formed at the 4.57 m line, confirming that in the retention-test both practice conditions led to the development of the same GMPs.
- Table 4 (p.66) shows no significance, nor any large effect size between either the pre- and retention tests for both the constant- and variable practice groups. Thus, no significant difference exists for change in relative timing patterns after the applied intervention program.
- This means that neither constant practice, nor variable practice conditions could cause especial skill emergence at the free throw line (4.57 m) in our current study

The hypothesis was **falsified** (*rejected*).

**Hypothesis 2**: *The constant practice condition group will demonstrate significantly better ($p$ < 0.05) shot proficiency with a large effect size compared to the variable practice condition group for the free throw distance (4.57 m) as a result of an applied intervention programme*.

- No statistically significant difference or large effect size was reported regarding the shot proficiency between the constant- and variable groups. In all cases the actual values were lower than the predicted values in the basketball free throw from the free throw line and the other distances after the regression line was calculated.
- As seen in Table 2 (p.87) in chapter four, the variable practice group showed a significant difference ($p$ = 0.001) between the actual and predicted values during the pre-test, as well as a large effect size according to Cohen's effect sizes (d = 1.020). Even though the retention test did not show any significant difference between the actual and predicted value in the retention test ($p$ = 0.835) nor did it show any effect size (d = 0.063), there was still no increase from the predicted value to the actual value.
- Moreover, as for the constant practice group, the pre-test showed a significant statistical difference between the actual and predicted values ($p$ = 0.019) with a large effect size (d = 0.831), with the actual proficiency significantly less than expected. Similarly, during the retention-test, the statistical significance ($p$ = 0.012) and large effect size (d = 0.949) also shows that actual performance were not as efficient as expected.
- In accordance, no especial skill emergence was confirmed through either the use of constant practice or variable practice at the free throw line (4.57 m), as no statistical significance ($p$ > 0.05), or any large effect size (d < 0.8) between the constant- and variable practice groups exist.

The hypothesis was **falsified** (*rejected*).

## 5.3. Limitations and recommendations

Our study did not provide enough support for either constant practice- or variable practice as a possible cause of the emergence of the basketball free throw especial skill. The method used to apply a training intervention programme over three days between the pre-test and retention-test did not confirm the hypothesis.

That being said, our findings suggest that certain shortcomings need to be considered when interpreting the results of this study.

- We tested the retention effect rather than immediate training effect as in a previous study (Breslin *et al*., 2012a). Whereas a post-test evaluates the immediate effects on skills performance following training, a retention-test would focus on the more permanent and long-term changes that are brought about by training methods, i.e. on learning effects.

- Our findings gave us no reason to confirm that different modes of training resulted in any significant difference in either kinematic parameter differences or shot proficiency. In addition, they did not confirm the result of especial skill emergence as predicted. Thus, the question of what exactly causes especial skill emergence remains unanswered.
- If we could have involved more participants, we would have been more likely to find statistical differences, however, the effect sizes would be smaller as there is a negative relationship between effect size and statistical significance (*p*-value). Hence, according to research, the magnitude of the effect was explained and the importance thereof discussed. Literature (Kühberger *et al*., 2014) found that studies using fewer participants or a smaller sample size would report a larger effect size, and vice versa. Hence, as the size of the sample decreases, the effect size will increase and the practical meaning of the results may be questioned.

In spite of the shortcomings of our study, the results provided a basis for further research regarding the emergence of especial skill. Research on the aspect of different training modalities as a cause of the uniqueness of certain skills, such as the basketball free throw, the baseball pitch and the 70 m archery shot, is still recent and has not been widely evaluated. Therefore, future research should focus on the principles of training modalities and retention, comparing the player's ability to recall and respond in novel situations.

Furthermore, future studies may address the problem of a limited number of participants by using more participants and increasing the subject pool. Such studies should also incorporate longer training periods (more than three days), and lastly focus on skills other than basketball or even overhead throwing actions. Skills such as darts, NFL-place kicks or soccer penalty kicks are proposed sport skills. Focusing on other skills will allow researchers to find the underlying cause of especial skill emergence, or at least come closer to the cause, and also allow them to broaden understanding of motor control theories and how these skills are stored in the memory. Last but not least, using kinematic analysis to focus on different skills would increase the validity and reliability of future studies.

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**APPENDIX A**

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

**HREC Stamp**

# PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR healthy young males (19-30 years old)

## TITLE OF THE RESEARCH PROJECT:

## Gaze behaviour and kinematics of especial skills

**REFERENCE NUMBERS: NWU-00180-15-A1**


**PRINCIPAL INVESTIGATOR: Dr Stanislaw H Czyz**

**ADDRESS:**

**Mail:** North-West University, Private Bag X6001, 2520, Potchefstroom, North-West Province, South Africa; Internal box #481

**Physical address:** PhASRec, building K3, 1st floor, room 111; Fanie du Toit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North-West Province; South Africa

**Email:** stanislaw.czyz@nwu.ac.za

**CONTACT NUMBER: +27 18 852625 or private cell phone: 079 271 8585**

You are being invited to take part in my research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

**This study has been approved by the** Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00180-15-A1) **and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.**

**What is this research study all about?**

- *This study will be conducted in the High Performance Institute of Sport at NWU,* Fanie du Toit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531 *and will involve a short questionnaire, 5 days of basket shooting (three training days and two test days, called pre- & post-tests). Pre and post-tests will include eye movement tests with the use of special glasses (so-called gaze behaviour pattern), description of your movement (what your movement looks like, so-called kinematic characteristic) and shot proficiency analysis (how good you were at shooting to the basket). The experienced movement science researchers trained in motor learning and approximately 20 participants will be included in this study.*

- *The objectives of this research (based on the entire project) are to determine:*

- differences between the gaze behaviours in throwing skills developed in same practice (constant) conditions[12] and throwing skills that were not trained
- differences between the gaze behaviours in throwing skills developed in different (variable) practice conditions
- differences between the movement you make (kinematic analysis) while throwing, using especial skill and skills, developed in variable practice

**Why have you been invited to participate?**

- *You have been invited to participate because you are a young healthy male with no previous experience in basketball, korfball or netball in a club*
- *You have also complied with the following inclusion criteria: you have not been injured at the time of testing and training.*

[12] Skills that are trained in the same conditions; for example throws with the use of the same ball, at the same distance, to the same basket that is at the same height during every training session are called especial skills.

- *You will be excluded if: you do not submit your informed consent form before the testing procedures commence; will be withdrawn from data collection in the instance of injury or illness; will be withdrawn from the study if you miss any of the five training days.*

**What will your responsibilities be?**

- *You will be expected to complete a brief questionnaire before you are tested and start practising. The questionnaire consists of a few questions regarding your age, history of injuries, and sport experience. On the first day of the study you will be expected to perform free throws from five different distances, 20 shots per each distance. You will practice shooting for the next three consecutive days, 100 shots per day. Depending on the group you will be selected to (randomly), you will practise either 100 shots a day from one distance (4.57 m from the basket) or 100 shots in total from five different distances (2.74 m, 3.35 m, 3.96 m, 4.57 m, 5.18 m, and 5.79 m, 6.4 m). During these five days you will perform a total of 500 shots. After three days of practice, you will perform the shooting test again: free throws from five different distances, 20 shots per each distance. The tests and trainings will last approximately 1 hour.*
- *During the tests and training you will be requested to wear special glasses, called eye-tracker, that allow monitoring gaze behaviour; this is how your eyes move. Additionally, a total of nine small reflective markers will be placed on your body for performance (kinematic) analysis. The markers will be placed directly on your skin on arms, shoulders, hips, legs. Ideally you will wear only tight pants and no shoes (without a shirt). However, you can also wear a sleeveless shirt, if you do not feel comfortable.*

**Will you benefit from taking part in this research?**

- The direct benefits for you as a participant will be the improved shooting skill. It may be useful if you decide to play basketball, korfball or netball with your friends or in a club. Also your abilities in eye-hand coordination will improve. You will have access to your results by means of a personal report.
- The indirect benefit will be a broadening of specialist sport science knowledge which can be transferred to the larger community. We will know more about how people become experts in their fields, which means what to do to become a specialist in motor skills. It is important not only in sport but also in everyday tasks: we move voluntarily while walking, speaking, eating, driving, cycling, etc. If one knows how people learn, one can think about creating a programme for re-learning (necessary for injured people).

**Are there risks involved in your participation in this research?**

- The risks in this study are: muscle soreness due to the amount of shots performed each day. The number of shots performed each day does not exceed a number of shots taken during ordinary basketball training (regardless of age and expertise of players). There is no evidence of throwing basketball possibly increasing the risk of injury. However, in case of muscle soreness, information will be provided on how to mitigate this symptom.
- The benefits outweigh the risk

**What will happen in the unlikely event of some form of discomfort occurring as a direct result of your participation in this research study?**

- *Should you have the need for further discussions after the testing or training day an opportunity will be arranged for you to talk to the exercise specialist about how to minimize the muscle soreness effect. You would be allowed to use the PhASRec facilities to perform additional exercises to avoid muscle soreness.*

**Who will have access to the data?**

- *To ensure the participants' right to privacy, confidentiality and anonymity, a confidential code will be assigned to each participant by means of a numbering system known only by the researchers. In the final dataset it will not be possible to identify a specific individual. Only the researchers will have access to the data.*
- *Data will be kept safe and secure by locking hard copies in locked cupboards in the researcher's office and for electronic data it will be password protected. (As soon as data has been transcribed it will be deleted from the recorders.) Data will be stored for 7 years.*

**What will happen with the data/samples?**

- *This is a once-off collection and data (anonymised) will be analysed in South Africa by the main investigator and by statisticians, if necessary.*

Will you be paid to take part in this study and are there any costs involved?

***No, you will not be paid to take part in the study but refreshments will be available.***

***There will thus be no costs involved for you, if you do take part.***

Is there anything else you should know or do?

- **You can contact Dr Stanislaw Czyz at +27 18 852625; stanislaw.czyz@nwu.ac.za if you have any further queries or encounter any problems.**
- **You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.**
- **You will receive a copy of this information and consent form for your own records.**

How will you know about the findings?

- **Please indicate (underline) preferred way of sharing with you the findings of the research (please note that you can change your choice during the whole study):**

  - **During a personal meeting with the researcher. You can provide the preferred date of meeting during the entire duration of the study:**

**...........................................................................................**

- **if via email - please provide your mail address here:**

**.............................................................................................**

Declaration by participant

By signing below, I ………………………………..…………. agree to take part in a research study titled: Gaze behaviour and kinematics of especial skills

**I declare that:**

- I have read this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have been grant an opportunity of asking questions to both the person obtaining consent and the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurized to take part.
- I may choose to leave the study at any time and will not be penalized or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ......................…........…………….. on (*date*) …………...……….. 20....

| | |
|---|---|
| ...................................................................... | ................................................................... |
| Signature of participant | Signature of witness |

**Declaration by person obtaining consent**

I *(name)* ………………………………………….……… declare that:

- I explained the information in this document to …………………………………..
- I encouraged him/her to ask questions and took adequate time answering them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) ......................…........…………….. on (*date*) …………...……….. 20....

**......................................................................** **..................................................................**

Signature of person obtaining consent Signature of witness

**Declaration by researcher**

I *(name)* …………………………………………..……… declare that:

- I explained the information in this document to …………………………………..
- I encouraged him/her to ask questions and took adequate time answering them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) ......................…........…………….. on (*date*) …………....……….. 20....

| | |
|---|---|
| **.....................................................................** | **.................................................................** |
| **Signature of researcher** | **Signature of witness** |

# APPENDIX B

## PARTICIPANT's PERSONAL INFORMATION FORM

**DATE: ................................**

| | | | | | |
|---|---|---|---|---|---|
| **NAME AND SURNAME (CAPITAL LETTERS):** | | | | | |
| **BIRTH DATE:** | dd/mm/yyyy | | | | |
| **PREVIOUS INJURIES** that caused medical attention and prevented you from every-day functioning for more than 8 days: | Date | Injury: | | | |
| **CURRENT INJURIES** that caused medical attention and prevented you from every-day functioning for more than 8 days: | | | | | |
| **HAVE YOU EVER BEEN TRAINING NETBALL, KORFBALL or BASKETBALL in a club?** | | Yes | | No | |
| When have you started (year): | | How long for (in months): | | How many times a week: | |
| When have you started (year): | | How long for (in months): | | How many times a week: | |
| **HAVE YOU EVER BEEN TRAINING ANY OTHER SPORTS?** | | Yes | | No | |
| What sport (name in capital letters): | | | | | |
| When have you started (year) | | How long for (in months): | | How many times a week | |
| What sport (name in capital letters): | | | | | |
| When have you started (year) | | How long for (in months): | | How many times a week | |

# APPENDIX C

PhASRec PHYSICAL ACTIVITY, SPORT & RECREATION | NORTH-WEST UNIVERSITY YUNIBESITI YA BOKONE-BOPHIRIMA NOORDWES-UNIVERSITEIT POTCHEFSTROOM CAMPUS

**NAME & SURNAME** : ______________________________________

**SUBJECT NUMBER** : ____

**EMAIL** : ______________________________________

**CONTACT NUMBER** : ________________

**AGE** : ____

**INJURY** : **YES / NO**

**DATE** : ________________

| **SHOT NR** | **3.35 M** *(C = 4.57 [1])* | **3.96 M** *(C = 4.57 [2])* | **4.57 M** *(C = 4.57 [3])* | **5.18 M** *(C = 4.57 [4])* | **5.79 M** *(C = 4.57 [5])* |
|---|---|---|---|---|---|
| **1** | | | | | |
| **2** | | | | | |
| **3** | | | | | |
| **4** | | | | | |
| **5** | | | | | |
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| **17** | | | | | |
| **18** | | | | | |
| **19** | | | | | |
| **20** | | | | | |
| **TOTAL** | | | | | |

**GRAND POINTS TOTAL:** ________

**CONSTANT / VARIABLE**

**TRAINING DAY (1 / 2 / 3) / PRE-TEST / POST-TEST**

*Constant [C] = only from 4.57 m (100 shots) → 4.57 [1] – 4.57 [5]*

# APPENDIX D

## GUIDELINES TO AUTHORS (Journal of Sport Sciences)

### Instructions for authors

Thank you for choosing to submit your paper to us. These instructions will ensure we have everything required so your paper can move through peer review, production and publication smoothly. Please take the time to read and follow them as closely as possible, as doing so will ensure your paper matches the journal's requirements. For general guidance on the publication process at Taylor & Francis please visit our Author Services website.

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The *Journal of Sports Sciences* is published on behalf of the British Association of Sport and Exercise Sciences, in partnership with the World Commission of Science and Sports and in association with the International Society for Advancement of Kinanthropometry. The emphasis is on the human sciences applied to sport and exercise. Topics covered also include technologies such as design of sports equipment, research into training, and modelling and predicting performance; papers evaluating (rather than simply presenting) new methods or procedures will also be considered.

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#### Structure

Your paper should be compiled in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list).

**Word Limits**

Please include a word count for your paper.

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# APPENDIX E

GUIDELINES TO AUTHORS (Journal of Motor Behaviour)

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## APPENDIX F

LANGUAGE EDITING LETTER (Chapter 1)

**M.B. BRADLEY**

**P.O. Box 37326**
**Faerie Glen**
**Pretoria 0043**

**072 369 5149**

# DECLARATION ON EDITING

**Student:** E. Pretorius

**Date:** 2019/03/18

| **Document submitted for editing** |
| --- |
| Chapter 1 of dissertation on basketball training |

The above chapter was submitted to me for language editing, which was done on 18 March 2019.

M.B. BRADLEY (MA) - Language editor

LANGUAGE EDITING LETTER (Chapter 2-5)


## M.B. BRADLEY

- **P.O. Box 37326**

**Faerie Glen**
**Pretoria 0043**

**072 369 5149**


## DECLARATION ON EDITING

**Student**: E. Pretorius

**Date:** 2019/03/12

| **Document submitted for editing** |
|---|
| Chapters 2 to 5 of dissertation on basketball training |

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# APPENDIX G

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## ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by **Health Research Ethics Committee (HREC)** on **06/11/2017**, the North-West University Research Ethics Regulatory Committee (NWU-RERC) hereby **approves** your study as indicated below. This implies that the NWU-RERC grants its permission that provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

**Study title: Relationships between constant and variable practice and kinematic characteristics of the basketball free-throw**

**Study Leader/Supervisor**: Dr SH Czyż
**Student**: E Pretorius-23551925

**Ethics number**: N W U - 0 0 1 1 7 - 1 7 - A 1

Institution / Study Number / Year / Status

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

**Application Type: Single study**

**Commencement date**: 01/11/2017 **Risk:** **Minimal**

**Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.**

**General conditions:**

*While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:*

- *The study leader (principle investigator) must report in the prescribed format to the NWU-RERC via HREC:*
  - *annually (or as otherwise requested) on the monitoring of the study, and upon completion of the study*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these amendments at the HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility the NWU-RERC and HREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the HREC or that information has been false or misrepresented,*
    - *the required amendments, annual (or otherwise stipulated) report and reporting of adverse events or incidents was not done in a timely manner and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *HREC can be contacted for further information or any report templates via Ethics-HRECApply@nwu.ac.za or 018 299 1206.*

The RERC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the RERC or HREC for any further enquiries or requests for assistance.

Yours sincerely,

**Prof. Refilwe Phaswana-Mafuya**
*Chair NWU Research Ethics Regulatory Committee (RERC)*

# APPENDIX H

ETHICAL CONSIDERATIONS IN STUDY

Prior to commencement of the project, permission was obtained from the Health Research Ethics Committee of the Faculty of Health Sciences at North-West University, to approach this dissertation as an affiliated study (See Appendix G). This affiliated study is subject to the original objectives and study design of the project “Gaze behaviour and kinematics of especial skills” (Ethics approval: NWU-00180-15-A1) set forth in the primary study, under supervision of Dr S.H. Czyz, who was the primary investigator.

A thorough warm-up took place prior to commencement of either the pre- or retention-tests. The primary investigator of this project, Dr Stanislaw Czyz, has been certified in the BLS (*Basic Life Support) for Health Providers* according to the American Heart Association (course completion: 18 May 2015). Also present was a qualified operator of an automated external defibrillator (AED) during the testing periods. Research was conducted in accordance with the declaration of ‘Ethics in Health Research: Principles, Process and Structure’, as well as that of Helsinki (2$^{nd}$ edition, Department of Health, South Africa, 2015). Complete Adherence to the NWU Manual for Master’s and Doctoral Studies (2013) for scientific research involving human individuals was followed in this study, and to the Ethical Principles and Guidelines for the Protection of Human Subjects of Research (i.e. Belmont Report), disseminated in 1979.

Dr Stanislaw Czyz (Primary investigator) ensured:

- Data storage: All the questionnaires and other hard-copy documents used during this study will be stored in a secure facility for a minimum of seven (7) years by the primary investigator, accessible to only the primary researchers, and thereafter documents will be destroyed by using a paper shredder. The data collected by means of the Qualysis system will be downloaded to a password-protected site immediately after each test day, with back-ups of the data stored on CD and external drives, stored for a minimum of seven (7) years, after which it will be destroyed. This will also be stored in a secure facility, and only be accessible to the primary researchers.

Before data analysis, the following have to be reassured, as stated by primary investigator (PI), Dr S.H. Czyz:

1. Final ethical approval letter for affiliated study had to be issued (NWU-00117-17-S1)

2. He (Elric Pretorius) will need to check in and – out the laptop equipment used to collect the data (i.e. raw data on laptop as biomechanical recordings) each day when he wishes to use it at building K3, from researcher Martenique Sparks, who keeps the laptop for the Qualysis system locked.
3. Quality control - Regular feedback is demanded by the research PI, and the process for data analysis is determined and run by the PI, even though the student does the data analysis. Random double checking (by PI) of the analysis will take place.
4. The kinematic data is coded, and the only file which can be used for participants' identification is stored by the PI in his locked cupboard.

# APPENDIX I

OPERATIONAL DEFINITIONS

For the purpose of understanding why we looked at the reason for the basketball free throw to be regarded as a unique skill amongst other basketball skills, and why several research studies have been done to determine exactly what caused this uniqueness, one has to understand the characteristics of the shot itself. Not only the understanding of the free throw shot, but also how players are trained and how memory is stored. Equally important is how this memory is utilized during a game, and if in fact, the way this skill is trained could be adapted by other movements. To understand and explain this, the first section will focus on introductory terms and definitions used throughout the dissertation.

**The following definitions clarify concepts used in this research study:**

**Ability**: refers to "a general trait or capacity of an individual that is a determinant of a person's achievement potential for the performance of specific skill" – however, a motor skill is a skill that focus specifically on the performance of a motor skill (Magill, 2011:49).

**Closed-loop theory**: according to research, this theory revolves around movements that are complimented with sensory feedback. Therefore, they create a memory representation as a result of the constant feedback from executing these specific movements (Magill, 2011:89).

**Closed Skills**: a closed skill is a skill with little to no changing variables, such as the especial skill (Keetch *et al*., 2005:976; Magill, 1989:404; Lotfi & Rahmani, 2015:863).

**Constant Practice**: the Oxford dictionary (2006) defines constant 'as something that occurs continuously and remain the same. Therefore in this study constant practice refers to a constant, repetitive training of only one variation of a certain skill. Thus, the word 'constant' refers to using 'one' variation to train a skill over a large amount of time. This training is also referred to as 'specific' form of training (Keetch *et al*., 2005:975).

**Especial skill**: can be defined as a one variation of a skill with a unique/distinct advantage amongst other variations of a skill within the same class of movements (governed by the same Generalized Motor Programme). Thus, in this instance, the basketball free throw at the distance 4.57 m has a unique advantage and is referred to as especial, due to its superior performance as compared to free throws taken at other distances. Another study referred to it as 'an exception to the rule' (Breslin *et* *al*., 2012:338; Czyz *et al*., 2013:139; Czyz *et al*., 2015:143; Fay *et al*., 2013:709; Keetch *et al*. 2005:976; Keetch *et al*., 2008:735; Simons *et al*., 2009:469; Stöckel & Breslin, 2013:536).

**Free throw**: the free throw shot is also known as a set-shot, or a foul-shot, and will be used as alternating terms throughout the chapter. This refers to a shot taken at the free throw line, also known as the foul-line, which is 4.57 m / 15 ft. from the basketball backboard (Keetch *et al.*, 2008:727).

**Generalized Motor Programme (GMP)**: refers to a memory representation of a certain skill being general enough to create a GMP, which could govern all skills within a certain class. This GMP is said to store the unchangeable features of any given movement. This term was introduced by Schmidt (1975, 2003) as a part of his Schema theory (Magill, 2011:91).

**Invariant features**: refers to certain key features of skills within the same class that are similar. This is in reference to three very important features – relative timing, relative force, and order of sequence. Thus, within any movement, these three things stay essentially invariant even though time, context etc. may differ or change. Different GMP's have different invariant features, thus, this is the main aspect differentiating different classes of movements (Magill, 2011:91).

**Jump-shot:** is defined as a shot taken whilst the player is airborne, thus, the player releases the ball while his feet are off the ground. This shot is the most commonly used shot in basketball as it can be used in general play, from any place on the court. The main difference between a jump-shot and a free throw is in the fact that a jump-shot can be taken in regular play as stated, whereas the free throw is taken from the same place each time and under the same conditions. Jump-shots have much more variability than free throws and as such, is also trained under different conditions. Due to the different movement structure (different order of sequences), jump shots are governed by different Generalized Motor Programs than free throws (Miller & Bartlett, 1993:287).

**Motor development**: it is the study of human development with special interest in motor – control and – learning (Magill, 2011:3).

**Motor learning**: focuses on the acquisition of motor skills, enhancing and improving motor skills and the reacquisition of skills after injury or disease (Magill, 2011:3).

**Motor programmes:** a 'memory based construct' that controls and coordinates movement (Magill, 2011:90)

**Open-loop theory**: in contrast, assumes that movements are not followed by feedback after execution. This was a theory more supported by Schmidt's Schema theory (1975), while the closed-loop theory is Adam's (1971) contradictive theory to that of Schmidt (Magill, 2011:89).

**Open Skills**: open skills are skills where variables from outside are unpredictable, thus, they can change a lot. No set variables exist, such as a jump-shot (Keetch *et al*., 2005:976; Magill, 1989:404; Lotfi & Rahmani, 2015:863).

**Overlearning**: large amounts of practice beyond what is needed to master a skill or task (Lotfi & Rahmani, 2015:863)

**Shot proficiency/efficiency**: is used alternatingly throughout to describe the success of a shot taken by a player, thus proficiency referring to the ability to shoot and an experiment testing it, while the efficiency was how successful that shot was.

**Variable Practice** on the other hand is contrasting to that of constant practice in that it refers to more than one variation of training used to train a certain skill. Variable is therefore defined as "not consistent or having a fixed pattern", (Oxford, 2006:1318). It can be seen as a more generalized method of training, as it is also referred to in this chapter (Breslin *et al*., 2012:154; Shoenfelt *et al*., 2002:1113).