Perceptual and Motor Processes during the Observation of Deceptive Actions

Theoretical Foundations and Practical Implications of the Head-Fake Effect in Basketball

Cumulative Dissertation

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Declaration of Authorship

I hereby formally declare that the present thesis with the title "Perceptual and motor processes during the observation of deceptive actions – Theoretical foundations and practical implications of the head-fake effect in basketball" is the result of my own work and that I have not used any auxiliaries other than those indicated. To the best of my knowledge and belief, I have marked all verbatim or indirectly taken over thoughts of other persons. Moreover, I assure that this dissertation has not been previously submitted, in whole or in part, for a degree or qualification at any university.

Danksagung

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Zusammenfassung

In verschiedenen Sportarten ist die Antizipationsleistung oftmals entscheidend für Sieg oder Niederlage. Deshalb nutzen Athleten Täuschungen, um die Antizipationsleistung ihrer Gegner zu verringern. Ein Beispiel dafür ist die Kopftäuschung im Basketball, bei der ein Spieler den Kopf in eine Richtung dreht, den Ball aber zur anderen Seite passt. In dieser Dissertation wurde einerseits der Frage nach den der Kopftäuschung zugrundeliegenden perzeptuell-kognitiven Mechanismen nachgegangen sowie andererseits Fragen mit Implikationen für die Praxis adressiert. Kapitel 2 stellt vier Experimente vor, die die perzeptuell-kognitiven Mechanismen der Kopftäuschung mit Videos untersuchten und dabei das Model der dimensionalen Überlappung (Kornblum et al., 1990) sowie die additive Faktorenmethode (Sternberg, 1969) nutzten. Insgesamt weisen die Ergebnisse auf eine Kombination von perzeptuellen Mechanismen und Interferenzen während der Antwortauswahl. In Kapitel 3 wurde untersucht, ob verschiedene zeitliche Abstände zwischen Kopfwendung und Pass die Größe des Täuschungseffekts beeinflussen. Der größte Täuschungseffekt konnte beobachtet werden, wenn die Kopfwendung kurz vor der Passbewegung gezeigt wurde. Kapitel 4 adressierte die Frage, wie unterschiedliche Manipulationen der Versuchssequenz den Täuschungseffekt bei Täuschungswiederholung beeinflussen. Dabei zeigte sich, dass das Ausführen von zwei Kopftäuschungen in schneller Abfolge den Täuschungseffekt eliminiert oder sogar zu einem Nachteil für den täuschenden Spieler führt. Außerdem wurde langanhaltende kognitive Kontrolle bei längeren Intervallen beobachtet, welche durch die vollständige Abwesenheit des Täuschungseffekts gekennzeichnet war.

Summary

In different spots, the ability to predict the actions of others is often decisive for win or loss. Therefore, athletes use various types of deceptive actions to lower the anticipation performance of their opponents. One example of this is the head fake in basketball, where a player turns the head to one side, but passes the ball to the other side. In this thesis, the perceptual-cognitive mechanisms underlying the head-fake effect were examined and questions with regard to practical implications were addressed. Chapter 2 presents four experiments, which investigated the perceptual-cognitive mechanisms of the head-fake effect with videos, using the model of dimensional overlap (Kornblum et al., 1990) and the additive-factors method (Sternberg, 1969). Overall, the results point to a combination of perceptual mechanisms and interference during response selection. In Chapter 3 it was examined, whether different temporal lags between head turn and pass influence the size of the head-fake effect. The largest fake effect could be observed, when the head turn was presented slightly before the passing action. Chapter 4 addressed the question how different manipulations of the trial sequence affect the head-fake effect. Results showed that applying two head fakes in rapid succession eliminates the effect or even leads to a disadvantage for the deceiving player. Moreover, longer-lasting cognitive control was observed for longer intervals, which was characterized by the complete absence of the head-fake effect.

The following chapters are based on the following publications:

Chapter 2

Polzien, A., Güldenpenning, I., & Weigelt, M. (2020). Examining the perceptual-cognitive mechanism of deceptive actions in sports: Different processes contribute to the head-fake effect in basketball. *Experimental Psychology, 67*(6), 349–363. https://doi.org/10.1027/1618-3169/a000503

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Chapter 3

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General Introduction

Chapter 1

Imagine you are riding your bike when suddenly a car approaches quickly from the right. Just because you realize what could happen in the next moment and therefore brake, you do not collide with the car. We often take this kind of prediction of the future for granted, however, it represents an astonishing accomplishment of the human brain. Such outstanding anticipation performances can also be found in sports, in which the anticipation of what will happen next might not be decisive for life or death, but is crucial for success. High time constraints make it necessary for athletes to anticipate the action of an opponent early, in order to initiate the appropriate reaction in time (Smeeton et al., 2019). In interactive sports, however, it is not only the anticipation of genuine actions that is important, but also of legal deceptive actions that are used by athletes to gain an advantage over their opponents. A variety of studies have been conducted to date to identify the factors that contribute to anticipation performance. The following section summarizes the state of research on the anticipation of genuine and deceptive actions in sports and focuses in particular on the head fake in basketball. Subsequently, sensorimotor and ideomotor approaches to the relationship between perception and action are explained. Finally, cognitive mechanisms of deceptive actions are considered against the background of the Theory of Event Coding (TEC; Hommel et al., 2001), before open issues are explicated and the research questions of this thesis are derived.

1.1 Anticipation of (Deceptive) Actions

Since the beginnings of anticipation research in the late 1970s, numerous studies have been conducted to determine what constitutes skillful anticipation performance in sports (Loffing & Cañal-Bruland, 2017; Williams et al., 1999). Early research on anticipation focused on the role of advanced postural cues and aimed to answer the question, what kind of kinematic information is relevant for anticipation and when during the observation of an unfolding movement this information is picked-up (Williams & Jackson, 2019). One key finding was that skilled athletes concentrate on different and earlier advanced postural cues and are able to discriminate an action during earlier movement phases as compared to less-skilled athletes (Abernethy, 1990; Müller et al., 2006). This insight is supplemented by the finding that athletes of different expertise levels also differ in their visual search behavior (Gegenfurtner et al., 2011; Mann et al., 2007). Skilled athletes often apply a different visual search strategy (Mann et al., 2007) and fixate more task-relevant areas as compared to novices (Gegenfurtner et al., 2011). While visual perception has been examined the most in anticipation research, other sensory modalities, like auditory perception, also contribute to anticipation performance (e.g., Cañal-Bruland et al., 2018; Klein-Soetebier et al., 2021). Research on the use of auditory information showed, for example, that the estimated length of a ball's trajectory in tennis is influenced by the intensity of the sound produced by the racquet-ball contact (Cañal-Bruland et al., 2018). Moreover, recent research has also shed light on the use of contextual information (i.e., non-kinematic information) for action anticipation. In this regard, athletes also seem to rely on other action-relevant aspects, like game score, field position, and action preferences of the opponent (Loffing & Cañal-Bruland, 2017; Williams & Jackson, 2019).

In recent years, research has focused not only on anticipation performance in recognizing genuine actions in sports, but also on how anticipation performance is affected by (legal) deceptive actions (for overviews see Güldenpenning et al., 2017; Jackson & Cañal-Bruland, 2019). Legal deceptive actions are actions that are permitted within the respective sport-specific rules and regulations and which are used by athletes to gain an advantage over the opponent (Steggemann, 2015; Weigelt & Güldenpenning, 2022).

The various deceptive actions in different sports can be divided into two types: those based on the presentation of misinformation and those based on the reduction of action-relevant information (Jackson et al., 2006; Weigelt & Güldenpenning, 2022; see Figure 1). The presentation of action-relevant misinformation aims at misleading the opponent into an incorrect judgment about the intended action, whereas the reduction of action-relevant information aims to make it difficult for the opponent to recognize the intended action, so that s/he may even have to guess (Jackson et al., 2006).

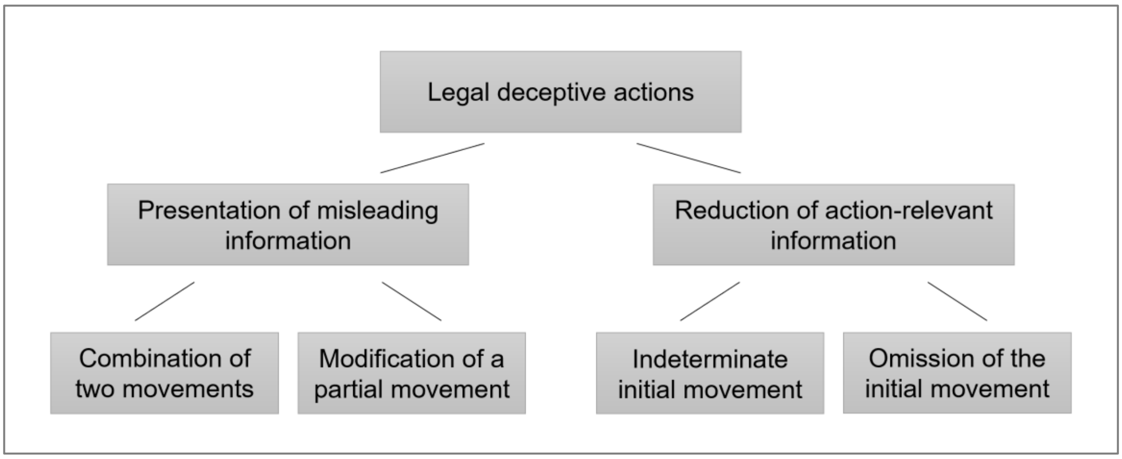

Figure 1. Taxonomy of deceptive actions in sports. From Weigelt & Güldenpenning (2022).[1]

The reduction of action-relevant information is achieved by either complete omission of the initial movement or by an indeterminate initial movement (Weigelt & Güldenpenning, 2022). An example for the reduction of action-relevant information can be seen in some martial arts where a roundhouse kick can be executed as a feint action. For this purpose, the leg is first brought up in front of the body as in a front kick, while the semi-circular movement of the roundhouse kick is executed as late as possible (Güldenpenning et al., 2015). This procedure withholds the action-relevant information so that the initial movement is indeterminate. An example for the reduction of action-relevant information by complete omission of the initial movement can be seen in team handball, when a hip shot is executed (almost) without backward movement of the arm (Weigelt & Güldenpenning, 2022). The other type of deceptive actions is based on the

[1] Translated from *Kognition und Motorik: Sportpsychologische Grundlagen und Anwendungen im Sport*, M. Weigelt & I. Güldenpenning, Kognitive Grundlagen von Täuschungshandlungen im Sport, p. 119, Copyright (2022), with permission from Hogrefe.

presentation of misleading information and can also be created in two ways: either two different movements are combined or a partial movement is modified (Weigelt & Güldenpenning, 2022). The combination of two different movements can be observed in team handball, in which a penalty taker can perform a fake shot. Instead of letting go of the ball during the fake shot, the player stops the movement and starts a new one (cf. Cañal-Bruland et al., 2010). A well-studied example of the presentation of misleading information by modification is the head fake in basketball, in which a basketball athlete turns the head into one direction, but passes the ball to the other direction in order to deceive the opponent about the direction of the pass (e.g., Kunde et al., 2011; Weigelt et al., 2017). Studies in various sports have been able to show that anticipation performance can be impaired when perceiving a deceptive action (e.g., rugby: Brault et al., 2012; Mori & Shimada, 2013; team handball: Cañal-Bruland et al., 2010; basketball: Güldenpenning, Kunde, & Weigelt, 2020b; Kunde et al., 2011).

Since the head-fake in basketball is particularly relevant to this work, the findings of previous studies will be presented here in more detail. In a typical experiment on the head fake, participants are shown images or videos of a basketball player performing either a pass without a head fake (i.e., congruent pass direction and head orientation) or a pass with a head fake (i.e., incongruent pass direction and head orientation). The participants' task is to respond to the direction of the pass, while at the same time ignoring the head orientation. The response is given with a simple button press (left vs. right) or a full-body blocking motion to the left or right (e.g., Alhaj Ahmad Alaboud et al., 2016; Güldenpenning et al., 2019; Kunde et al., 2011; Weigelt et al., 2017). The head fake leads to the so-called head-fake effect in the opponent, which is characterized by slower and more error-prone reactions of the opponent as compared to reactions to passes without a head fake (e.g., Güldenpenning et al., 2018; Güldenpenning, Kunde, & Weigelt, 2020b; Kunde et al., 2011; Weigelt et al., 2020). While at the beginning it was not clear which directional information, head orientation or gaze direction, is automatically processed and leads to the head-fake effect (e.g., Kunde et al., 2011), Weigelt et al. (2020) showed that it is indeed the head orientation, which triggers a conflict during information processing.

In general, the head-fake effect has been found to be very robust and could be observed with static and dynamic stimuli as well as for simple and complex responses (Alhaj Ahmad Alaboud et al., 2016), and when participants were instructed to ignore the head and the gaze orientation (Güldenpenning et al., 2019). Furthermore, the head-fake effect is found not only in novices, but also in basketball athletes (Güldenpenning, Kunde, & Weigelt, 2020b; Weigelt et al., 2017), and after extensive practice (Güldenpenning, Schütz, et al., 2020). Nevertheless, practice seems to at least reduce the effect (Güldenpenning, Schütz, et al., 2020), as does cognitive load (Güldenpenning, Kunde, & Weigelt, 2020a), and a high overall fake frequency (Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018). Another factor that has been found to reduce the head-fake effect, at least in some studies, is the repetition of the head fake in rapid succession. Some studies found a reduced head-fake effect in the case of two deceptions in direct succession (e.g., Friehs et al., 2020; Güldenpenning et al., 2018; Güldenpenning, Kunde, & Weigelt, 2020a). This effect is referred to as the congruency sequence effect (CSE; e.g., Egner, 2007). However, other studies could not find a CSE for the head-fake effect (Kunde et al., 2011) or only observed it in some experiments or groups (e.g., Alhaj Ahmad Alaboud et al., 2012; Weigelt et al., 2017).

The head fake is often compared to classical psychological conflict tasks (e.g., Güldenpenning, Schütz, et al., 2020; Kunde et al., 2011), such as the Simon task (Simon, 1969) and the Stroop task (Stroop, 1935), which also lead to interference effects arising from the processing of conflicting information. Based on the model of dimensional overlap (Kornblum et al., 1990), Kunde et al. (2011) identified two possible causes of interference during head fakes: On the one hand, the head fake could cause perceptual (stimulus-stimulus) interference between the pass direction and the head orientation, while on the other hand, the head fake could lead to stimulus-response interference caused by the dimensional overlap between the irrelevant stimulus feature and the response, which affects response selection processes. In different experiments, Kunde et al. (2011) tested these possibilities. The results suggest a perceptual cause of the head-fake effect when using static images.

Apparently, research in the last decades has gained some insights into several aspects regarding the anticipation of deceptive actions. In addition to the question of which factors do or do not influence the effectiveness of deceptive actions, another interesting question is, how (deceptive) information is processed in the brain. The long research history of human information processing has produced various theories on this topic. The most wide-spread theories are outlined in the next sections. In cognitive psychology, the processing of sensory input and the generation of an appropriate output is often explained by stage theories, which are based on a sensorimotor view of information processing.

1.2 The Sensorimotor Approach

When a tennis player reacts to a serve or when a goalkeeper saves a penalty, it seems obvious that the athlete must perceive the action of the opponent at first and must react to it afterwards. The idea, that perception is the beginning and action is the result, reflects the sensorimotor approach to action control. The basic idea of the sensorimotor approach was already formulated by the French philosopher Descartes (1664), who assumed that action control is achieved by three types of processes, afferent, central, and efferent processes, respectively. During afferent processes, information is picked up through sensory organs and send forward to the central organ, which generates efferent commands. These commands are sent to the musculature during efferent processes in order to execute an action. While the exact way in which Descartes (1664) believed the processes should proceed seems improbable from today's perspective, the general structure is still the basis of many models in cognitive psychology (Hommel et al., 2016).

Ever since Descartes’ (1664) early concept of action control, many researchers aimed to find out, what happens between a sensory input and a motor output. Because the internal aspects of information processing are not directly observable, the main goal of reaction time studies has long been to discover and establish processing stages by manipulating tasks or task variables (Sanders, 1980). In the 19th century, the Dutch physiologist Donders developed a now well-recognized method to study mental processes (Hommel et al., 2001). Donders (1868), conducted a series of experiments and examined, how additional mental processes affect the physiological time (i.e., the time between stimulus and response). In one experiment, participants had to respond with the hand to the shining of a light. This experiment consisted of two conditions: a) simple reaction to a light and b) a choice reaction, which consisted of a response to a red light with the right hand and to a white light with the left hand. Donders (1868) assumed that the additional time needed for the response in the second condition was the time, which is necessary for making the decision. In another series of experiments, Donders (1868) asked his participants to respond to the sound of vowels by uttering the same vowel. There were three different tasks: a) response to a known vowel, b) response to different vowels, and c) response to only one of different vowels. Donders (1868) developed the so-called subtraction method to determine the duration of different mental processes. To this end, the author calculated the difference between task c and task a to determine the duration of the conception of a sound (i.e., stimulus discrimination; cf. Kunde, 2017). Moreover, Donders (1868) assumed the difference of reaction times between task b and a to be the time necessary for the stimulus discrimination and the corresponding expression of the will (i.e., response selection; cf. Kunde, 2017).

Donders’s subtraction method has been criticized early on. Külpe (1893) remarked that the method is based on the prerequisite that the change of the task only leads to an additional mental process, but that it does not change anything else (e.g., preparation, sensory stimulation, reaction), and that this prerequisite was not verified. However, Külpe (1893) also pointed out that the measurement of compound reactions was of particular importance, regardless of whether the calculation of the duration of individual mental processes was permissible. The author explains this by the fact that this type of measurement enables a more precise analysis of the individual components and the determination of the influence that various conditions exert on the course of the reaction (Külpe, 1893).

After almost a century of little continuation of Donders's work, the research community again became more interested in mental processes and Donders's research was revived (Hommel et al., 2001). Sternberg (1969) developed the additive-factors method (AFM), which uses reaction time data to infer the structure of mental processes. In contrast to Donders, Sternberg’s (1969) aim was not to measure stage durations and he also did not add or delete stages. However, the method was based on Donders idea that successive functional stages take place between stimulus and response and that these stages contribute additively to the total reaction time (Sternberg, 1969). On the basis of this idea, Sternberg (1969) assumed that any two experimental factors, which influence different stages, should also have an additive effect on reaction times. Furthermore, any two factors, which influence the same stage, should interact with each other. Hence, this logic can be used to discover new stages, if one finds two factors, which have an additive effect on reaction times (Sternberg, 1969).

The sensorimotor approach, then, is a view of the relationship between perception and action in which perception and action are to be understood as separate entities that cannot communicate directly with each other. Instead, different stages or processes occur between a stimulus and a response, requiring a translation of perception into action. Because the stages proceed sequentially from perception to action, these types of models are referred to as linear stage models (Hommel et al., 2001; Sanders, 1983). The sensorimotor approach should be seen as an overarching construct within which different authors have proposed different theories and, in particular, different stages within stage models. For example, Donders (1868) determined twelve subprocesses. By combining some of these processes, the following four main processing categories can be postulated: sensory (pre-)processing, stimulus identification, response selection, and response initiation (Hommel et al., 2016). Sanders (1980) has designated six different stages, namely preprocessing, feature extraction, identification, response choice, response programming, and motor adjustment (see Figure 2). Sanders (1990) pointed out that, depending on the task, additional stages may also be necessary, such as memory search, which would hopefully not affect this basic structure.

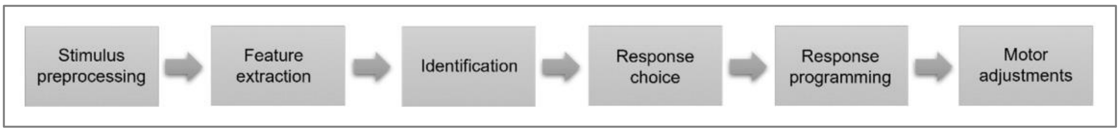

Figure 2. Stage model of information processing as proposed by Sanders (1980).

These examples illustrate that stages within stage theories can usually be labeled as either perceptual or motor. An exception is the response selection stage, which is sometimes classified into an independent decision category (Sanders, 1990). The general division into perceptual and motor stages makes clear that within linear stage models it is usually assumed that perceptual and motor codes are separate. While afferent codes refer to patterns of stimulation, efferent codes contain information about bodily movements (Prinz, 1990). Due to these different functions and thus, also different formats of the codes, some kind of translation process must take place, which links perception to action (Prinz, 1997; Welford, 1960). For this reason, Massaro (1990) adopted the basic structure of Sanders' (1980) model but replaced the response choice stage with a percept-act (perception-action translation) stage. As an example, for the translation problem the author mentions the task of naming an object. In this task, the object must first be identified and the information about the object must then be translated into code that can be used for response selection (Massaro, 1990).

Over time, there has been debate not only about the number of stages and about the translation problem, but also about other assumptions made with regard to stage models. The main aspects are discussed in the next sections.

1.2.1 Discrete vs. Continuous Processing

In the 1960s and 1970s, the view was widespread that stages within information processing were discrete and that a stage could not begin until the processing of the previous stage was complete (cf. Hommel et al., 2001). In fact, this assumption was fundamental to Sternbergs’ (1969) additive-factors method. However, different authors challenged this view and proposed a continuous flow of information processing (e.g., Eriksen & Schultz, 1979; McClelland, 1979; Meyer et al., 1985), which at the same time led to the questioning of the validity of Sternbergs’ (1969) additive-factors method (cf. Miller, 1988; Sanders, 1990).

Miller (1988) noted that the dichotomous classification into discrete and continuous is a severe simplification. Following Bower (1975), Miller (1988) uses the term *representations* to refer to passive codes that store information and the term *stages* to refer to active operators that use and modify representations. The author explains that within typical information processing models, each individual stage receives an input in the form of a representation, which is then processed and transformed. As a result, a new representation is created, which, in turn, serves as input for the next stage. Miller (1988) argues that within such models the terms discrete and continuous can refer to three different aspects: First, a stage can be characterized as discrete or continuous depending on the available input and output representations. Thus, a stage can be characterized as discrete if the possible codes are clearly distinguishable from each other. In contrast, a stage could be characterized as continuous if the possible codes can be arbitrarily similar. Second, a stage can be called discrete or continuous depending on how transformations are performed. If the transformation from one code to the next takes place in the form of an all at once principle, the transformation can be called discrete. If, on the other hand, the transformation is gradual, it can be called continuous. The third aspect relates to the transmission of information. If one stage must be completed before the next can begin, the stage can be described as discrete. However, if there can be a temporal overlap between the stages (i.e., stage N+1 begins processing of partial information, while stage N is not yet completed), they can be called continuous (Miller, 1988).

Since discrete stages were originally among the basic assumptions of Sternbergs' (1969) additive-factors method, several authors addressed the implications of possibly continuous information processing for the applicability of the AFM (e.g., Massaro & Cowan, 1993; Sanders, 1990). Based on the different forms of discreteness and continuity formulated by Miller (1988), Sanders (1990) argued that not all forms of discreteness were necessary for the applicability of the AFM and assumed that discrete stages within the AFM referred mainly to constant stage output. The author further stated that the generation of a discrete internal code was indeed necessary for the AFM. However, whether the constant stage output was obtained through a discrete or continuous transformation within a stage was less relevant. Last, discrete transmission from one stage to the next was desirable, but not necessary in every case. Overall, Sanders (1990) concludes that the AFM is less dependent on discrete stages than originally thought.

1.2.2 Serial vs. Parallel Processing

The question of discrete versus continuous processing is closely related to the question of serial versus parallel processing (Miller, 1988; Sanders, 1990). Whereas the question of discrete versus continuous processing relates to a single item, serial versus parallel processing is concerned with how an entire stimulus field can be processed (Massaro & Cowan, 1993). In this regard, parallel processing means that all elements (to be processed) are processed simultaneously, whereas serial processing means that each element is processed individually, one after the other (Townsend, 1971). Massaro and Cowan (1993) explain that different stages can operate in parallel, but that when following a particular input through the system, the operations are run in sequential order. Whether individual stages are capacity-limited or can process multiple items in parallel would have to be determined separately for each stage.

Goodale and Milner (1992), for example, proposed a model with two different visual pathways, the dorsal and the ventral stream, within visual information processing. While the ventral stream is responsible for the formation of perceptual representations, the dorsal stream is used for the visual control of actions, such as grasping an object (Goodale & Milner, 1992; Milner & Goodale, 2008). From today's point of view, (purely) serial processing seems improbable (Millroth, 2021). However, there are indications that information processing can neither generally be described as serial nor generally as parallel, but that the type of processing depends on various factors (Townsend & Fifić, 2004). For example, within a short-term memory search task, Townsend and Fifić' (2004) results indicate that the type of processing (serial or parallel) differed between different individuals as well as changed within single individuals for different conditions.

1.3 The Ideomotor Approach

While the sensorimotor approach was most prevalent for decades or centuries and remains relevant today, other ideas, now influential, about the relationship between perception and action originated in the 19th century and are grouped under the term ideomotor approach. The term “ideomotor” is believed to have been introduced by Carpenter (1852; cf. James, 1890/1981). Carpenter (1852) attempted to explain several parapsychological phenomena in which an "operator" influenced a person’s thinking or actions, such as the person not being able to get up from the chair. The author argued that it was not the will of the operator that controlled the person’s sensations, but a suggestion from the operator that triggered a corresponding *idea* in the person’s mind. In this context, then, the term refers to Carpenter's consideration that mere ideas can influence motor actions (Carpenter, 1852). Later, James (1890/1981) adopted the term and took the reasoning further:

> *"An anticipatory image, then, of the sensorial consequences of a movement, plus (on certain occasions) the fiat that these consequences shall become actual, is the only psychic state which introspection lets us discern as the forerunner of our voluntary acts."* (James, 1890/1981, Vol. 2, p. 501)

Obviously, a major difference between sensorimotor and ideomotor approaches lies in the assumption of the cause of actions: Whereas sensorimotor theories assume that stimuli are the starting point of actions, ideomotor theories assume that actions are triggered by the intentions of the agent (Hommel et al., 2001).

In history, many other authors have dealt with the ideomotor principle (for a historical overview, see Stock & Stock, 2004). However, the idea formulated by James (1890/1981), that human action is initiated by its own sensory consequences, that is, by the effects that usually occur during the execution of the same action, is still understood today as the basis of many ideomotor theories (cf., Moeller & Pfister, 2022; Stock & Stock, 2004).

1.3.1 Common Coding of Perception and Action

The ideomotor principle suggests that perception and action are closely linked to each other. The Common Coding approach can be regarded as the functional architecture that can be assumed within the ideomotor principle (Prinz, 2005). If one imagines a task in which a subject must respond to a green or red light by pressing a button with the left or right hand, then the question arises as to the mechanism linking color and hand (Prinz, 1997). Events in the environment (such as the light signal in the example) lead to stimulation of the sensory organs and subsequently to the generation of sensory codes in the brain. However, stimulation of muscles (those of the hand in the example) occurs through motor codes in the brain that represent specific excitation patterns of the effectors (Prinz, 1997). Traditional theories, like linear stage models of information processing, are based on the idea of separate codes of perception and action and therefore, require a translation process between the two (see Section 1.2). In contrast, the common coding approach claims that perceived events and planned actions are coded in a common representational domain (Prinz, 1990, 1997). Figure 3 illustrates the basic idea of common coding (Prinz, 1997). While traditional approaches assume the translation from sensory to motor codes (see Figure 3, solid arrows), common coding assumes a common overarching architecture in which perception and action are represented together through perceptual codes (see Figure 3, broken lines; Prinz, 1997). In this regard, the difference in perception and action codes lies not in the form in which both are present, but in the role they take: Perception codes refer to events in the environment that are to be represented, whereas action codes refer to events that are to be generated in the environment (Prinz, 1990). For this, the actions to be achieved are not represented in the form of the individual proximal steps necessary, but rather in the form of the distal sensory consequences to be achieved by these actions (e.g., Hommel et al., 2001; Prinz, 1997; van der Wel et al., 2013). One consequence of this common coding architecture is, that two people have a similar representation of an event that is performed by one person and observed by the other (cf. van der Wel et al., 2013).

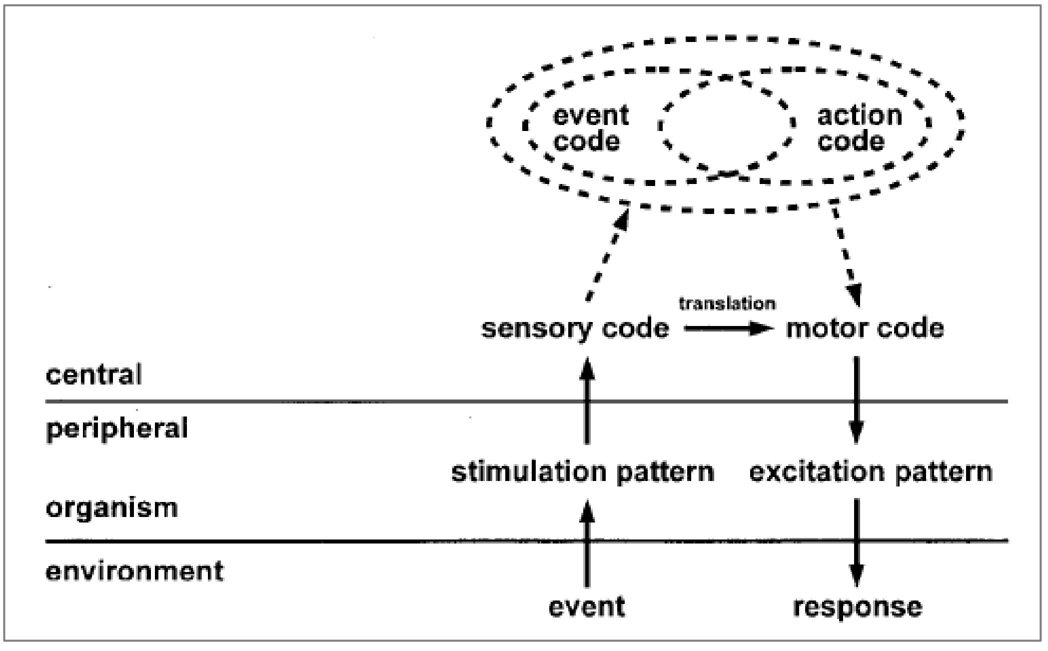

Figure 3. Relationships between perception and action. From Prinz (1997).[2]

[2] Reprinted from *European Journal of Cognitive Psychology*, *9*(2), W. Prinz, Perception and action planning, p. 130, Copyright (1997), with permission from Taylor & Francis.

1.3.2 Ideomotor Theory and Action Simulation

The ideomotor principle states that a voluntary action is induced through the imagination of its sensory consequences (James, 1890/1981). The common coding of perception and action is considered a functional architecture that allows actions to be initiated by their sensory consequences (Prinz, 2005). This close link between perception and action, however, seems to harbor further implications concerning the impact of perception on action and vice versa. The bi-direct link between perception and action is shown in Figure 4 (Schütz-Bosbach & Prinz, 2007). Here, on the one hand, perceiving another person's action seems to affect one's own production of action (motor resonance; e.g., Schütz-Bosbach & Prinz, 2007; Wilson & Knoblich, 2005). On the other hand, generating actions leads to selective sensitivity of one's own perception to similar or related actions of other persons (perceptual resonance; Knuf et al., 2001; Schütz-Bosbach & Prinz, 2007).

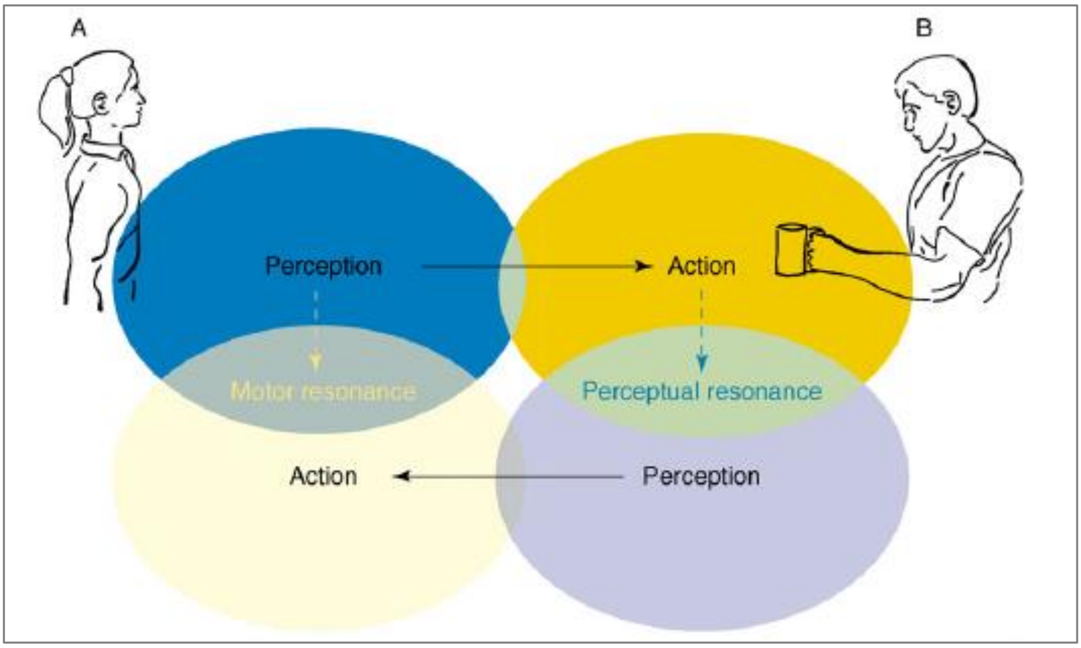

Figure 4. Motor and perceptual resonance. From Schütz-Bosbach & Prinz (2007).[3]

The term motor resonance refers to the observation that the motor system of humans is activated when observing the action of another individual (e.g., Schütz-Bosbach

[3] Reprinted from *TRENDS in cognitive Science*, *11*(8), S. Schütz-Bosbach & W. Prinz, Perceptual resonance: action-induced modulation of perception, p. 350, Copyright (2007), with permission from Elsevier.

& Prinz, 2007; Uithol et al., 2011). A specific type of neurons, the so-called mirror neurons, are often assumed to be the neurophysiological basis for such resonance effects (Schütz-Bosbach & Prinz, 2007). First found in the brain of macaque monkeys, it could be observed that mirror neurons were active, both when the monkeys performed a movement themselves and when they observed the same movement by another actor (e.g., Di Pellegrino et al., 1992; Gallese et al., 1996). Later, evidence was found that mirror mechanisms (e.g., Hari et al., 1998; Gazzolla & Keysers, 2009; Iacoboni et al., 2005) and mirror neurons (Mukamel et al., 2010) also exist in humans. The activation of the mirror system in monkeys and in humans during action observation could serve the understanding of actions (Fabbri-Destro & Rizzolatti, 2008) and thereby could, among other things, have a learning function (Jeannerod, 2001), but also serve action anticipation (e.g., Aglioti et al., 2008; van der Wel et al., 2013). In this context, Aglioti et al. (2008) studied the anticipation performance and neural correlates of a group of expert basketball athletes with visual and motor expertise, a group of coaches[4] and sports journalists with visual expertise only, and a group of novices without visual and motor expertise. As expected, the athletes showed the best anticipation performance. The athletes with the visuo-motor expertise as well as the group with the visual expertise showed a selective increase of motor-evoked potentials during action observation. During erroneous throws, however, only the athletes showed a (time-specific) motor activation. Overall, Aglioti et al.'s (2008) study indicates that both, the combination of visual and motor expertise and "pure" visual expertise lead to motor resonance, with the additional motor experience of the expert athletes seemingly leading to more accurate action simulation and thus, better action anticipation (Aglioti et al., 2008).

In order to draw a complete picture of the connection between perception and action based on mirror mechanisms, Schütz-Bosbach and Prinz (2007) argue that not only the observer must be taken into account, but also the actor himself. In this regard, the assumption of common representations of action and perception should lead not only to an influence of perceived movements on one's own actions (i.e., motor resonance), but also from one's own action to the perception of similar actions (i.e., perceptual resonance). Schütz-Bosbach and Prinz (2007) assume that perceptual resonance is

[4] The coaches used to be basketball players but stopped playing an average of 9.4 years ago.

a key component for social interactions, as it plays a role in sympathy, empathy, and joint action. Perceptual resonance effects appear as both online and offline effects. In the case of online effects of perceptual resonance, a currently planned or executed movement has a direct effect on perception (Schütz-Bosbach & Prinz, 2007). Online effects have been shown in various experiments and are characterized by either impaired perception (contrast effects; e.g., Hamilton et al., 2004; Zwickel et al., 2007; Zwickel et al., 2010, Experiments 1 to 4) or facilitated perception (assimilation effects; e.g., Repp & Knoblich, 2007; Zimmermann et al., 2013; Zwickel et al., 2010, Experiment 4) of similar actions or associated action effects.

In addition to online effects of perceptual resonance, several studies have also shown offline effects, in which action and perception processes are separated in time (Schütz-Bosbach & Prinz, 2007). One kind of offline effects is based on motor expertise and shows that motor experience with a movement can influence the perception of the same movement. For example, Calvo-Merino et al. (2006) used an fMRI study to examine the influence of motor experience on neuronal activation during action observation, while at the same time controlling the effect of visual experience. For this purpose, female and male ballet dance experts watched videos of female and male specific ballet moves. While both genders had visual expertise with all movements shown, motor expertise existed only for the respective gender-specific movements. Moreover, in order to estimate the confounding effect of gender congruency, additional gender-common stimuli were presented, which are usually performed by both genders. The dancer showed an expertise-dependent greater premotor, parietal, and cerebellar activity, when observing movements from their own movement repertoire in comparison to movements for which no motor expertise was available. These findings suggest that by observing an action, the associated motor representation can be activated (Calvo-Merino et al., 2006). The results by Calvo-Merino et al. (2006) show how action, even if performed at an earlier time, can influence perception.

1.3.3 Ideomotor Learning and its Generalization

An assumption that follows almost naturally from the basic assumption of ideomotor theory is that connections of actions and their sensory consequences must first be learned, so that the sensory consequences can be used to initiate voluntary actions (cf. Moeller & Pfister, 2022; Prinz, 2005). This so-called ideomotor learning leads to the formation of action-effect associations (cf. Moeller & Pfister, 2022; Stock & Stock, 2004). In fact, the question about the connection between the will to perform an action and the motor implementation that produces the desired effects in the environment predates the formulation of the ideomotor principle by James (1890/1981). Herbart (1825), for example, stated that already newborns perform movements from purely organic reasons, which in turn lead to sensations in the soul, whereby the connection of movements with their consequences arises. The importance of such involuntary movements of young children was also emphasized by Harleß (1861), who noted that the play of the mind with the motor apparatus of the nervous system has no less relevance than the play of children has a recognized pedagogical importance. Moeller and Pfister (2022) gave the example of an infant who learns what happens when s/he activates certain muscles. S/he perceives, sees, and feels, for example, that the leg stretches. Thus, the infant learns the association between the motor activity and the resulting sensory consequences, i.e., the action effects. Once the association has been formed, the movement can be initiated through anticipation of the extended leg (Moeller & Pfister, 2022).

Based on the experiments and learning-theoretical consideration by Greenwald (1970) and the assumptions postulated by the Common Coding theory (Prinz 1990; 1997), Elsner and Hommel (2001) proposed a two-stage model of action control. Stage one of this model reflects the idea of an acquisition phase, in which infants learn associations between actions and effects through randomly generated motor patterns. The resulting change between infant and environment is registered and leads to a pattern of activation in the cognitive system. Through temporal overlap of the activation of motor and sensory codes, these are integrated. The second stage of the model addresses the question how the appropriate and functional movements for goal-directed actions can be selected. In this regard, the second stage includes the assumption that the activation of the effect code co-activates the associated motor pattern to a certain extent. While the activation of the response codes through the effect codes is automatic, the authors assume that response selection could additionally be controlled by intentional processes (Elsner & Hommel, 2001). The last consideration was already formulated by Harleß

(1861), who remarked that we would wriggle to death, if every imagination of earlier executed movements would lead to a renewed execution. For this reason, Harleß (1861) assumed that the will to perform the movement must come together with the idea of the result of the movement so that the action is actually performed.

Elsner and Hommel (2001) note that the principle of acquiring new relationships between movements and their effects is not exclusive to children. Even if adults are familiar with many movements, they are put in a similar situation as an infant when, for example, they learn to handle an unfamiliar electronic device (Elsner & Hommel, 2001). The learning of new associations between actions and effects in adults has also been shown previously in several studies (e.g., Herwig & Waszak, 2012; Hoffmann et al. 2009; Pfister et al., 2011).

Another issue related to the learning of action-effect relationships concerns how frequently a stimulus must occur together with an effect for an association of the two to occur. In this context, studies have shown that few couplings (Wolfensteller & Ruge, 2011) or even a single coupling of action and effect is sufficient (Janczyk et al., 2012). However, the question arises whether such associations represent long-lasting learning or short-term binding of actions and effects.

1.3.4 The Anticipatory Behavioral Control (ABC) Framework

Based on the ideomotor principle, Hoffmann (1993, 2003, 2009) developed a framework called anticipatory behavioral control (ABC). Hoffmann (e.g., 2003, 2009) assumes that voluntary actions always serve to achieve a desired outcome or effect. The anticipation of the effects to be achieved therefore precedes the voluntary action. In a primary learning process, action-effect representations are formed by comparing actual effects with anticipated effects. If there is sufficient conformity, new connections are formed or existing connections are strengthened. When there is little conformity, new connections are not established or existing connections are weakened (Hoffmann, 2003, 2009). Importantly, the framework also takes the situational context into account, which is integrated in a secondary learning process. For example, applying the brake will bring a car to a stop on a dry road, while it is likely to swerve on an icy road (Hoffmann, 1993). Thus, an action can be associated with different effects depending on the context.

If a certain result is to be achieved, the corresponding action-effect representation is activated. In the case of situation-dependent effects, the stored conditions are compared with the current condition to find the most similar situation. Furthermore, within the ABC theory it is assumed that stimuli that match a represented condition are assumed to evoke the readiness to produce the outcome, provided that the outcome has been produced repeatedly before in the same situation. (e.g., Hoffmann, 2003, 2009).

1.3.5 The Theory of Event Coding (TEC)

The Theory of Event Coding (TEC; Hommel et al., 2001) represents another more recent approach to the cognitive bases of action control that is also rooted in the ideomotor theory. Since TEC also makes use of other theories, it can be called a metatheoretical framework (Hommel, 2009; Hommel et al., 2001). Just like the original ideomotor idea, TEC assumes that goals are an essential part of actions. Nevertheless, the approach also attributes importance to external factors. In this context, Hommel et al. (2001) assume that re-actions are also voluntary actions and voluntary actions can also be called reactions. The latter becomes obvious when imagining a voluntary action like opening a door: The goal of the action cannot be sufficient to specify it, since external factors have to be taken into account. The former becomes clear when imagining an experiment in which the participant has to choose one of several responses in response to different stimuli. For the corresponding reaction, however, the previous instruction and the intention of the participant to respond appropriately are necessary (Hommel et al., 2001).

To serve as a framework for understanding perception and action planning, TEC involves several basic assumptions. In this regard, TEC's core functional structure consists of the common representation of perception and action (Common Coding, see Section 1.3.1). Perception and action planning are considered functionally equivalent because both are viewed as an internal representation of external (distal) events (Hommel et al., 2001). Distal coding in this context means that different features of a stimulus are represented that are relevant for both, perception and action planning. In this sense, the distance a hand should move to an object should correspond to the perceived distance to that object (Hommel, 2019). On the other hand, proximal effects on the sensory surface or muscular innervation patterns, may not be the same components of perception and action planning (Hommel et al., 2001).

A further assumption within TEC is that the entire information belonging to a stimulus is presented in a distributed manner (i.e., distributed neuronal code). There is no evidence that information about a stimulus or event is stored anywhere united (Hommel, 2019). On the contrary, research on the visual system in particular indicates that individual features are processed at different locations (cf. Singer & Gray, 1995). The association of different features to a stimulus could happen through temporal synchronization of feature codes (Milner, 1974; Singer & Gray, 1995). However, TEC does not make any assumptions about the concrete integration mechanism (Hommel et al., 2001).

Possibly most important within TEC, is the assumption of event files. For simplicity, Hommel et al. (2001) use the term “event” in the sense of an easily distinguishable occurrence in the world (e.g., a flash of light) or a single action (e.g., a keystroke). An event file consists of the individual distal feature codes that represent an event. Feature codes can be easy (e.g., color or form), but can also be more complex or abstract (e.g., “sit-on-ableness”). It is also clear from the nature of the feature codes that they are not specific to a stimulus or response. Moreover, feature codes can also change over time, so that, for example, different shades of red can be learned to distinguish. The learning process manifests itself in a differentiation of what used to be a single feature code for red into multiple feature codes of the different shades of red (Hommel et al., 2001). When perceiving or planning an event, various feature codes are integrated into an event file. While short-term binding effects occur when certain feature combinations occur for a limited time (e.g., Gordon & Irwin, 1996; Kahneman et al., 1992), frequent repetition creates permanent event files that are stored in long-term memory (e.g., a strawberry might be stored as small and red; cf. Hommel, 2019). In this sense, there is a difference between online feature binding and long-term learning. Short-term bindings to online files may be based on neural synchronization (Hommel & Colzato, 2009). In contrast, learning is thought to be based on structural changes. Whether and how short-term online feature bindings can be converted to permanent memory files, is still unclear (Hommel, 2019).

TEC assumes that when an action is planned or an event is perceived, all associated features are activated. For example, seeing a green apple can activate various feature codes associated with an apple, such as “green”, “round”, “edible”, and so on. However, before a feature is bound, it also primes other representations that include that specific feature code. Seeing something green, for example, can thereby facilitate saying “green” (Hommel, 2019).

Even if all features associated with an event are activated, the activation of different features is not necessarily equal. This is based on a weighting of features that is related to the current goals of the agent (e.g., Hommel et al., 2001; Memelink & Hommel, 2013). Thus, if a particular feature is especially relevant to a task, then the basic activation level of the feature code is increased relative to the resting level. Which features are then actually bound in an event code depends on the level of activation of the individual features: Features with higher activation levels are more likely to be integrated in an event file and their representation might be stronger as compared to less activated features (Hommel et al., 2001). Interestingly, the weighting mechanism always seems to refer to an entire dimension (e.g., “location”) rather than a single value within a dimension (e.g., “left”; Memelink & Hommel, 2013). In terms of perception, this feature weighting can be referred to as an attentional process, since it prepares the cognitive system for the preferential processing of relevant features. In the context of action planning, feature weighting refers to an agent's intention to bring about a particular aspect of an event to be produced (Hommel et al., 2001).

1.3.5.1 TEC and the Simon Task

Hommel (2019) explained various assumptions and implications of TEC using different versions of the Simon task. Here, the basic assumptions of TEC for the classical Simon task will be briefly summarized, since this classical conflict task will be of importance in the course of this thesis. In the Simon task, a stimulus (e.g., auditory or visual) is presented to the left or right side of a participant. The participant is instructed to respond to a stimulus feature, such as color or pitch, by pressing a button (left vs. right). Even though the location of the presentation of the stimulus is irrelevant to the task, it affects the performance of participants: Response times are shorter when presentation location and response side match (e.g., both left) compared to when they do not match (e.g., stimulus left and response right), which is referred to as the Simon effect (e.g., Simon, 1969; Simon & Rudell, 1967).

According to Hommel (2019), the instruction for this task results in two event files being formed, one for the left response and one for the right response. A file for the left response could consist of feature codes for the left hand, the index finger, the left button, and the color of the relevant stimulus (e.g., black). For the right response, there would be a similar file with the corresponding right spatial codes and the assigned relevant color (e.g., white). Since color and key location are task-relevant, they are weighted higher than the other features. Provided that the black stimulus is presented on the left side or the white stimulus on the right side (i.e., stimulus and response sides correspond to each other), only the features for the correct response are activated. However, if the black stimulus is presented on the right (i.e., non-corresponding) side, the coding of the location as "right" will also activate the feature codes for “right hand” and “right key”. This activation of the “incorrect” feature codes will result in a conflict, which will affect response selection and therefore, slow down the response (Hommel, 2019).

1.3.5.2 TEC and the Head-Fake Effect in Basketball

In the previous subsection, the assumptions of TEC were explained using the Simon task, which is considered a classical psychological conflict task. In this section, TEC will be related to an applied context, namely an attack-defense interaction in sports. A typical one-on-one situation can be found in basketball when an attacking player executes a pass and a defending player aims to intercept the pass with a blocking movement (cf. Güldenpenning, Kunde, & Weigelt, 2020a). In such situations the so-called head fake can be used by the attacking player to reduce the anticipation performance of the opponent and to prevent a successful defense (e.g., Güldenpenning, Kunde, & Weigelt, 2020a; Kunde et al., 2011).

The head-fake effect (i.e., slower and more error-prone responses in case of a head fake) has been demonstrated in several studies and different moderating factors have been identified (see Section 1.1), but the cognitive mechanisms underlying the head-fake effect have been little explored. However, the head-fake effect is assumed to be based on a conflict between the relevant pass direction and the irrelevant head orientation during information processing (cf. Güldenpenning, Kunde, & Weigelt, 2020a).

Weigelt and Güldenpenning (2022) have used TEC as an approach to explain the underlying perceptual-cognitive mechanisms from a theoretical perspective, which will be briefly summarized here. Given the assumptions of TEC, the instructions in a typical head-fake experiment should result in the formation of two event files, one file for each response side (see Figure 5).

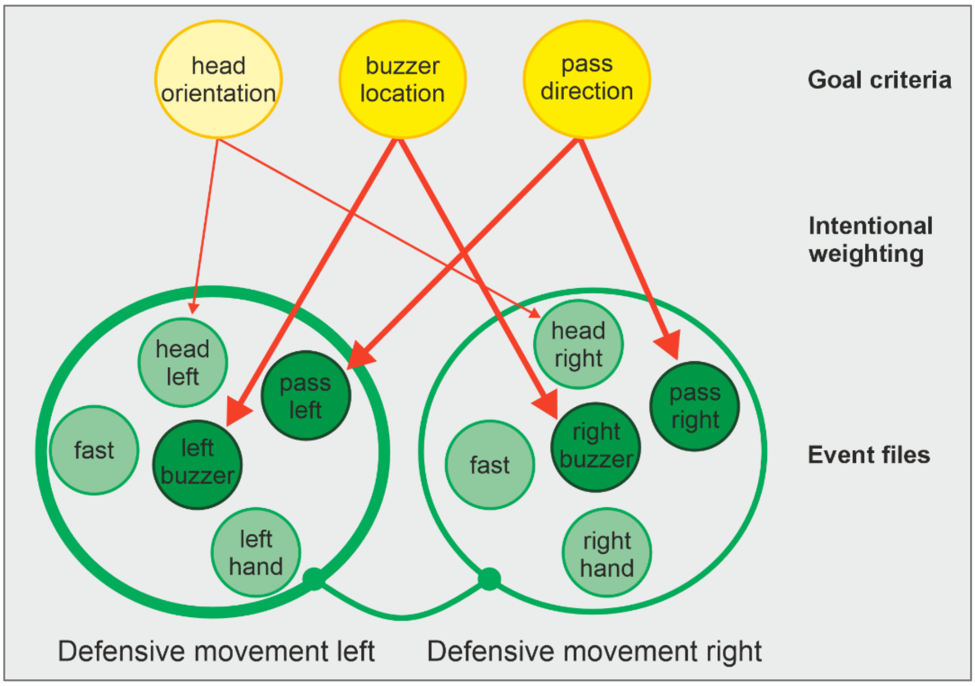

Figure 5. Event files in a task on the head-fake effect in basketball as assumed by TEC. From Weigelt & Güldenpenning (2022), based on Hommel (2019).[5]

According to Weigelt & Güldenpenning (2022), the event file for the response to the left could contain the left pass direction and the left head orientation as spatial stimulus-related features and the left response side as a spatial response-related feature. Other aspects, such as that the response should be executed quickly, are also

[5] Translated from *Kognition und Motorik: Sportpsychologische Grundlagen und Anwendungen im Sport*, M. Weigelt & I. Güldenpenning, Kognitive Grundlagen von Täuschungshandlungen im Sport, p. 126, Copyright (2022), with permission from Hogrefe.

represented. A similar file will be generated for the right response. Based on the instruction, two feature codes should be heavily weighted, the one for the pass direction and the other for the response side. When the head orientation (e.g., left) corresponds with the pass direction (e.g., left), the event file for the correct response (i.e., left response side) will be activated. The activation takes place through the relevant feature (i.e., pass direction) and the irrelevant feature (i.e., head orientation) based on dimensional overlap of the features, even though the activation by the irrelevant feature should be lower. The result is a fast and error-free execution of the response. However, when the head orientation (e.g., right) is incongruent to the pass direction (e.g., left), the different spatial codes cause a processing conflict similar to that in classical conflict tasks (such as the Simon task, see Section 1.3.5.1). While the pass direction activates the event file for the left response, the head orientation activates the event file for the right response, which slows down the response or even leads to the activation of the associated motor pattern and the execution of the incorrect response (Weigelt & Güldenpenning, 2022).

1.4 Open Issues

In the last decade, the head fake in basketball has been used as a paradigmatic example for deceptive actions in sports. Many studies have been conducted on the head fake in order to identify factors relevant to its effectiveness (e.g., Güldenpenning et al., 2018; Güldenpenning, Schütz, et al., 2020). The head-fake effect, characterized by slower and more error-prone responses to passes with head fakes as compared to passes with consistent head orientation (Kunde et al., 2011), has been shown to be extremely robust (e.g., Güldenpenning et al., 2019; Weigelt et al., 2017). An explanation for this robustness is that the processing of the head turn can hardly be suppressed (e.g., Güldenpenning, Kunde, & Weigelt, 2020b; Kunde et al., 2011). According to Kunde et al. (2011), the automatic processing of the head orientation results in a perceptual conflict, when it does not correspond to the pass direction. This conflict must first be solved before response selection can take place (Kunde et al., 2011). While Kunde et al. (2011) have presented convincing evidence that this is true for the perception of head fakes presented in static images, it remains an open question whether a purely perceptual conflict is also the cause of the head-fake effect in the case of dynamic stimuli or whether a conflict in response selection also occurs. In particular, different mechanisms could be expected, since static images *“do not capture the dynamic nature of the essential information available”* (Abernethy et al., 1994, p. 191). The assumption of a conflict during response selection would be supported, at least in theory, by TEC (Hommel et al., 2001), since TEC suggests that the head turn can activate the event file of the incorrect response and thereby is able to trigger a conflict with the event file of the correct response (cf. Hommel, 2019; Weigelt & Güldenpenning, 2022).

If the head orientation during a head fake activates the incorrect event file, the question arises, if a head turn, which is executed some time before the pass could influence the size of the head-fake effect, depending on how long it takes until the activation of an incorrect event file is cancelled again. This aspect is interesting not only from a theoretical perspective, but also from a practical perspective: The greater the induced fake effect, the greater the advantage over the opponent.

Another aspect that is relevant from a practical perspective is the question of the effectiveness of the deception in the case of rapid repetition. However, research results on this topic are heterogeneous. While some studies have found a reduced or completely disappeared head-fake effect when two head fakes were performed directly one after the other (e.g., Friehs et al., 2020; Güldenpenning et al., 2018; Güldenpenning, Kunde, & Weigelt, 2020a), other studies could not find this reduction of the head-fake effect (Kunde et al., 2011) or only observed it in some experiments or groups (e.g., Alhaj Ahmad Alaboud et al., 2012; Weigelt et al., 2017). Therefore, the question arises what is decisive for the occurrence of a so-called congruency sequence effect for head-fake repetitions.

1.5 Research Questions and Hypotheses

The present thesis has two overarching aims: first, to shed light on the underlying mechanisms of the head-fake effect with dynamic stimuli, and second, to identify factors influencing the effectiveness of head fakes in basketball. The specific questions, which were addressed in seven Experiments, will be briefly summarized below. In the general discussion, the individual results will be brought together and considered in particular with regard to the assumptions of the Theory of Event Coding (TEC; Hommel et al., 2001).

Chapter 2

In this chapter, the question of the perceptual-cognitive mechanisms of the head fake in basketball with dynamic stimuli is addressed. To this end, four experiments are presented, which systematically examined the influence of different manipulations on the head-fake effect (cf. Kunde et al., 2011). In Experiment 1, the dimensional overlap between the irrelevant stimulus feature (i.e., head orientation) and the response was removed by changing the response keys from horizontal to vertical. Based on the model of dimensional overlap (Kornblum et al., 1990), it was assumed that the head-fake effect should disappear in the vertical condition if the effect is based on response selection processes, but should still be present if it is based exclusively on perceptual interference between pass direction and head orientation. In Experiments 2 to 4, the additive-factors method (AFM; Sternberg, 1969) was applied. In Experiments 2 and 3, the possibility of a perceptual origin of the head-fake effect with dynamic stimuli was directly addressed. For this purpose, the image quality of the videos was reduced, since signal quality is assumed to affect the perceptual stage of feature extraction (Sanders, 1983). With reference to AFM (Sternberg, 1969), it was assumed that an interaction between pass type (no head fake vs. head fake) and image quality (normal vs. reduced) would indicate a stimulus-stimulus interference, whereas an additive effect between the two variables would indicate a different origin of the head-fake effect for dynamic stimuli.

In Experiment 4, response-selection processes were examined by combining the head-fake stimuli with the spatial Simon task. For this, the ball in the video was colored either blue or yellow. Instead of reacting to the direction of the pass, participants were asked to react to the color of the ball by pressing a left or right response key. Since the Simon effect is attributed to interference during response selection (for a review, see Lu & Proctor, 1995), following AFM (Sternberg, 1969), an interaction between type of pass and stimulus-response congruency should point to response selection as the location of the conflict, whereas an additive effect would rule out this origin.

Chapter 3

The aim of Experiment 5 was twofold: first, to further investigate the underlying mechanisms of the head-fake effect, and second, to address the question of the optimal temporal lag between head turn and pass during the execution of a head fake, in order to generate the largest possible head-fake effect. To this end, three static images were used, which induced the perception of an apparent motion (cf. Alhaj Ahmad Alaboud et al., 2012). In the first image, the athlete was looking straight into the camera with the basketball in front of his chest, the second image contained the sole head turn and in the third image, the pass was shown. The stimulus-onset asynchrony (SOA) between the head turn, and the pass was varied between 0 and 800 ms. Here, it is important to note that the experimental paradigm in this experiment is comparable to spatial cueing experiments. Based on spatial cueing studies (e.g., Langdon & Smith, 2005), it was expected that the preceding head turn would initially activate the corresponding response. Consequently, the participants should be able to execute the response immediately if the target does not contain a deception. In the case of a head fake, however, the incorrect activation would first have to be canceled before the correct response could be initiated, which should result in slower responses. This typical head-fake effect should be modulated depending on the SOA. Specifically, while the activation of the event file corresponding to the head orientation should not be fully built up for short SOAs, it will be gone for long SOAs.

Chapter 4

Another aspect of interest from both a theoretical and a practical perspective relates to the repetition of the deceptive action. The question in this context is whether the head-fake effect is reduced or even eliminated with repetition. This consideration results from research on the congruency-sequence effect (CSE; e.g., Duthoo et al., 2014; Egner, 2007) in various conflict tasks (e.g., Simon or Stroop task), which could show that the occurrence of the conflict as well as the size of the congruency effect depends on the previous trial. In Experiment 6 and 7, temporal aspects of successive trials were manipulated in order to gain insights into the occurrence of the CSE for the head-fake effect. In Experiment 6, the response-stimulus interval (RSI) between the response to the previous target and the onset of the next target was varied (500 ms, 2000 ms, 5000 ms). In Experiment 7, the inter-stimulus interval (ISI; i.e., the interval between two targets) was manipulated (500 ms, 2000 ms, 5000 ms). Based on previous research on the CSE (e.g., Alhaj Ahmad Alaboud et al., 2012; Duthoo et al., 2014; Egner, 2010), it was expected that the head-fake effect could be observed in both experiments. However, it was assumed that the CSE would be dependent on the length of the interval (cf. Alhaj Ahmad Alaboud et al., 2012; Egner et al., 2010): A CSE was expected for the short and medium RSI and for the short and possibly medium ISI. No CSE was expected for the long intervals, as it is assumed that the adjustments leading to the CSE are cancelled again with such long time in between.

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Examining the perceptual-cognitive mechanism of deceptive actions in sports

Chapter 2

Abstract In several kind of sports, deceptive actions are used to hinder the anticipation performance of an opponent. During a head fake in basketball, a player turns the head to one side, but passes the ball to the other side. A pass with a head fake generates a head-fake effect in the observer, which is characterized by slower and more error-prone responses to the pass direction as compared to passes without a head fake. Whereas the head-fake effect has been replicated several times, the question of its origin with dynamic stimuli has not been answered yet. The present study includes four experiments, which are conducted to examine the perceptual-cognitive mechanism underlying the effect by using the model of dimensional overlap (Kornblum et al., 1990) and the additive-factors logic (Sternberg, 1969). Results point to multiple processes contributing to the head-fake effect for dynamic stimuli, which operate not only at a perceptual level, but also at a level of response selection.

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Author contributions:

AP, IG, and MW conceived the study. AP was in charge of overall direction and planning of the experiments. AP analyzed the data. AP wrote the manuscript with helpful input from IG and MW.

2.1 Introduction

In any sports, which involve one or more opponents, deceptive actions are used to deceive the opponent(s) about the true action intention or to produce a premature reaction in the observer(s) (for a review on deceptive action, see Güldenpenning et al., 2017). A paradigmatic example for a deceptive action in sports is the head fake in basketball. During a head fake, a basketball player turns the head to one side, but passes the ball to a teammate on the opposite side. Several studies with static and dynamic stimuli have shown that the response to the pass direction is slower and more error-prone, when a head fake is observed as compared to the response to an observed pass without a head fake (e.g., Alhaj Ahmad Alaboud et al., 2016; Kunde et al., 2011; Weigelt et al., 2017). The head-fake effect arises from a conflict of information processing between the task-relevant feature pass direction and the task-irrelevant feature head orientation. Thus, the head-fake effect reflects an interference effect, which can readily be observed in a number of interference paradigms in cognitive psychology, such as the Stroop task (Stroop, 1935) and the Eriksen flanker task (Eriksen & Eriksen, 1974). Accordingly, the head-fake effect is based on the automatic processing of the head orientation, which cannot be suppressed (Kunde et al., 2011). A recent study showed that it is indeed the head orientation and not the gaze direction, which is driving the effect (Weigelt et al., 2020). Moreover, the head-fake effect can be found in novices and in basketball experts (Güldenpenning et al., 2020a; Weigelt et al., 2017), after extensive practice (Güldenpenning, Schütz, et al., 2020), and with simple as well as complex response modes (Alhaj Ahmad Alaboud et al., 2016). However, the size of the head-fake effect can be modulated by different factors and is (somewhat) reduced when the overall fake frequency is high (Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018), when a fake has been observed in the preceding trial (congruency-sequence effect; e.g., Güldenpenning et al., 2018; Güldenpenning, Schütz, et al., 2020), and under cognitive load (Güldenpenning et al., 2020b).

Besides these findings, which are particularly relevant for practical demands, another interesting aspect from a theoretical perspective is the question about the perceptual-cognitive mechanism of the head-fake effect. According to Kornblum et al.'s (1990) model of dimensional overlap, interference effects can emerge from three different sources: 1) a stimulus-stimulus (S-S) interference, caused by an overlap between relevant and irrelevant stimulus features, 2) a stimulus-response (S-R) interference caused by an overlap between the irrelevant stimulus feature and the response, and, 3) a S-R interference caused by an overlap between the relevant stimulus feature and the response (Kornblum et al., 1990). Referring to this model, the head-fake effect in basketball could be caused by an interference of head orientation and pass direction or an interference of head orientation and response. The overlap between pass (relevant stimulus feature) and response cannot cause an interference, because pass direction and response are always compatible (cf. Kunde et al., 2011).

Based on this model of dimensional overlap (Kornblum et al., 1990), Kunde et al. (2011) conducted a series of experiments to identify the locus of the head-fake effect. Their first experiment implemented the new paradigm and represents the basic experiment (cf. Kunde et al., 2011, Experiment 1): Static images of a basketball player were used, who passed the ball to the left or right. In half of the trials, head and pass were co-aligned (i.e., no head fake), in the other half, pass and head were oriented to different directions (i.e., head fake). Participants were asked to respond to the pass direction and to ignore the gaze direction by pressing a left key for a pass to the left and a right key for a pass to the right. Results revealed longer reaction times and higher error rates for passes with a head fake as compared to passes without a head fake. This finding was named the head-fake effect and was afterward replicated several times (e.g., Alhaj Ahmad Alaboud et al., 2016; Güldenpenning, Kunde, & Weigelt, 2020a; Weigelt et al., 2017). In another experiment, Kunde et al. (2011, Experiment 3) changed the response key arrangement from horizontal to vertical to cancel out the dimensional overlap between head orientation and response. Using this experimental setup, the head-fake effect should disappear, if it was based on (S-R) interference between the task-irrelevant stimulus feature and the response. However, results revealed a head-fake effect of the same size as in the basic experiment, pointing to an S-S overlap being responsible for the effect. In two further experiments, Kunde et al. (2011, Experiments 4 and 5) applied Sternberg's (1969) additive-factors logic. This approach allows to examine the influence of different information processing stages on the basis of reaction time data. The main idea is that during information processing, different, more or less discrete stages (or processes) work successively on an input to create an output. Therefore, the duration of each stage is assumed to be additive to the time needed for the whole chain of processes to be completed (Sternberg, 1969). Sternberg (1969) put forward the idea of four main stages to affect binary classification tasks. These stages relate to 1) stimulus encoding, 2) serial comparison, 3) binary decision, and 4) translation and response organization (response selection). More generally, information processing can be divided into perceptual processing, decision making (response selection), and the generation of the appropriate motor response (Sanders, 1990). These superordinated stages might be composed of different components. The perceptual stage, for example, could include stimulus preprocessing, feature extraction, and identification. The motor stage could contain motor programming and motor adjustment. Some tasks might also involve other processes, for example memory search (Sanders, 1990).

It should be noted in this context, however, that Sternberg (1969) used the term "stages" early on, but was cautious with a precise definition of these "stages". He viewed each of these stages as being "one of a series of successive processes that operates on an input to produce an output" (see Sternberg, 1969, p. 282). Ever since, however, his work has been mostly viewed to focus on stages as being completed one after each other, and not on how these make use of newer information during ongoing action events. With regard to how the impact of stages and processes on information processing should be viewed, we like to argue as follows: Focusing primarily on information processing within separate stages might work for experimental tasks with static stimuli, in which the input does not change. But in our daily life, the environment is constantly changing, so that our information processing system must deal with new information all the time. In this regard, Sternberg (2011) remarks in his newer conception of his approach that the assumption of a stage model does not exclude the assumption of feedback: "There is no reason why a later stage cannot make use of new sensory information (such as feedback) in (re)processing earlier sensory information" and views stages rather as so-called mental-process modules, focusing on the subprocesses that run independent and serve a distinct function. Therefore, to avoid misunderstanding, we use the term process to differentiate it from the previously used term of stages in the following. This is primarily to change the focus to the underlying perceptual-cognitive mechanism based on different information processes, when observing more complex actions, such as the head fake in basketball.

In the context of conflict tasks, the question to be answered is usually, if the conflict arises within perceptual processing or during response selection (e.g., Simon & Berbaum, 1990). According to additive-factors logic, two factors, which influence different processes (e.g., a perceptual process and response selection), should therefore have an additive effect on reaction times. In contrast, two factors, which influence the same process (e.g., a perceptual process) should interact and produce an over-additive effect (Sternberg, 1969, 2011). The application of the logic is based on an experimental design, which contains one factor, which is known to influence a specific process (e.g., a perceptual process), in order to determine the locus of the other factor. Kunde et al. (2011, Experiment 4) used the experimental setup of their basic experiment but reduced the image quality in half of the trials. The image quality is assumed to influence the perceptual processing of the stimulus. The authors found a significant interaction effect, which was due to a larger head-fake effect with reduced image quality compared to normal quality. According to additive-factors logic, the authors concluded that the head-fake effect has a perceptual origin. To further corroborate this assumption, Kunde et al. (2011, Experiment 5) conducted another experiment and used a Simon task to influence response selection processes. In this experiment, the same stimuli were used as before, but the ball was colored either red or green. Participants were instructed to respond to the color of the ball by pressing a left or right key. The authors hypothesized an interaction effect, if the head fake is caused by an S-R interference, but an additive effect, if the origin is perceptual. Results revealed two significant main effects for pass-head congruency and Simon-type congruency, but no significant interactions between both factors. Therefore, the authors concluded that the head-fake effect in basketball originates on a perceptual level from an S-S interference (Kunde et al., 2011).

A detail of the original experiments by Kunde et al. (2011), which were conducted to isolate the locus of the head-fake effect, was that only static images were used as targets. Thus, these images did not contain any dynamic information about the spatial and temporal unfolding of the key parameters of the deceptive action. It could therefore be argued that S-S interference is the primary locus of the head-fake effect, as put forward by Kunde et al. (2011), however, this finding might be specific for static images. More realistic stimuli transporting dynamic information, in contrast, could induce automatic tendencies to act (e.g., imitation), as has already been shown for the observation of other persons (Bach & Tipper, 2007, Experiment 1; Brass et al., 2001). Dynamic stimuli thus could lead to different results, including multiple sources of interference effects.

First evidence for different mechanisms with different stimuli comes from Polzien et al. (2021). The authors examined the time course of the head-fake effect as a function of different temporal lags between head turn and passing movement. To this end, a sequence of static images was used, which induced an apparent motion in the observer (Alhaj Ahmad Alaboud et al., 2012; Polzien et al., 2021). Each trial consisted of the initial position (basketball player oriented towards the front, ball in front of the body), the head turn to the left or right, and the passing movement to the left or right side. The stimulus-onset asynchrony (SOA) between head turn, and passing movement varied between 0 ms and 800 ms. Results showed that the head-fake effect increased from SOA 0 ms to SOA 300 ms (33 ms) and again decreased to SOA 700 ms. The authors argued that this inverted u-shaped function of SOA reflects a response activation, which gradually builds up and subsequently decays (Eimer et al., 1995). Moreover, the authors put forward the idea of different mechanisms being responsible for the head-fake effect, depending on the type of stimuli and the response modality, which are used (Polzien et al., 2021). This consideration is strengthened by typically much larger head-fake effects with dynamic stimuli compared to static stimuli (Alhaj Ahmad Alaboud et al., 2016).

Additional evidence that the head fake might not only work on a perceptual level comes from Schütz et al. (2020). The authors instructed their participants to respond to the pass direction of a basketball player by performing a full body movement, while standing on a force plate. The subliminal presentation of incongruent head orientations influenced reactions on a motor level as reflected by a shift of the center of mass into the wrong direction (Schütz et al., 2020). The latter effect of response priming on participants' postural control was also observed in other studies using dynamic stimuli to investigate deceptive actions in sports, for example, an initial movement into the wrong direction during the observation of a running fake in rugby (Brault et al., 2012). Henry et al. (2012) found an increased movement time in football players reacting to another player, who performed a direction change with a feint compared to a direction change without a feint. This effect is also assumed to be based on an initial movement into the wrong direction (Henry et al., 2012).

The present study aims at uncovering the perceptual-cognitive mechanism of the head-fake effect in basketball with more realistic stimuli. To this end, a series of four experiments, based on the study of Kunde et al. (2011) mentioned above, was conducted. In contrast to Kunde et al. (2011), videos were used instead of static images. In all four experiments, we expected to find the typical head-fake effect. In accordance with the model of dimensional overlap by Kornblum et al. (1990), the research strategy was to systematically examine different perceptual-cognitive processes, as reflected by S-S and/or S-R interference effects, which could potentially contribute as a source to the head-fake effect. Experiment 1 targeted response-selection processes by varying between a horizontal and a vertical response-key arrangement, respectively, to cancel out the dimensional overlap between the irrelevant stimulus feature (head orientation) and the response. By doing so, the manipulation was implemented on the response side (i.e., targeting response-related aspects affecting the match/mismatch of stimulus and response during response-selection processes). If the head-fake effect with dynamic stimuli (i.e., videos) is based on S-R interference, the head-fake effect should disappear in the vertical response-key arrangement. However, if the effect is still present under the vertical response-key arrangement, the head-fake effect would have a different source than S-R interference driven by response selection, such as S-S interference. Experiment 2 and 3 used the horizontal response-key arrangement, but the image quality of the videos was reduced. This manipulation directly addresses stimulus-related aspects affecting the encoding of spatial information in terms of a match/mismatch of spatial information affecting perceptual processes. In this regard, it represents a "classical" experimental manipulation to examine perceptual processes and to test for the overlap between relevant and irrelevant stimulus features. In accordance with the additive-factors logic (Sternberg, 1969), an interaction of the type of pass and image quality would point to S-S interference as a source of the head-fake effect, whereas an additive effect of type of pass and image quality would indicate a different source of the head-fake effect. Experiment 4 examined response-selection processes by using the well-established spatial Simon-task (Craft & Simon, 1970; Hommel, 1994; Simon, 1969). In this experiment, the manipulation was achieved by varying the stimulus side (i.e., targeting stimulus-related aspects affecting the match/mismatch of stimulus and response during response-selection processes). Here, an interaction between the type of pass and spatial S-R congruency would show that response-selection processes can be another source of the head-fake effect, for as long as the processing of (spatial) stimulus features is central to response selection, whereas additive effects for the type of pass and spatial S-R congruency would rule out response selection processes to be affected by the head fake.

2.2 Experiment 1

Experiment 1 was based on the model of dimensional overlap (Kornblum et al., 1990) and its application for determining the origin of the head-fake effect in basketball by Kunde et al. (2011). It aimed at investigating response-selection processes by removing the dimensional overlap between the task-irrelevant stimulus feature (head orientation) and the response. To this end, the key arrangement was changed from horizontal to vertical. By doing so, the match/mismatch between stimulus and response was varied by manipulating response-related aspects of the task. In contrast to Kunde et al. (2011), the factor key arrangement was manipulated as a within-subject factor and videos instead of static images were used.

2.2.1 Methods and Materials

Participants An *a priori* power analysis using G*Power 3 (Faul et al., 2007) was conducted to compute the required sample size to reach an interaction effect. Since it is not possible to estimate sample sizes for repeated measures designs with G*Power directly, we used an adjustment of the *f*-value, suggested by Rasch et al. (2010). This adjustment is only applicable for within-subjects designs in which at least one factor has only two levels, which is the case in our study. The adjusted *f*-value is calculated as follows: $f' = \sqrt{p} * f = \sqrt{2} * 0.25 = 0.3536$, where *p* reflects the number of factor levels of the two-levels factor. The number of levels of the second factor is considered in G*Power as “repetitions”. The correlation among repeated measures was set to a conservative value of 0.3, in order not to overestimate the power. Results suggest a sample size of $N = 24$ participants for the interaction in this 2 x 2 repeated-measures design (given $f' = 0.3536$, $\alpha = 0.05$, $1\text{-}\beta = 0.8$)[6]. Twenty-four participants without any specific expertise in basketball (14 females, 2 left-handed, $M_{age} = 23.3$ years, $SD = 5.8$) took part voluntarily in this experiment. Course credits were offered for participation. All participants reported normal or corrected to normal vision, were naïve with regard to the purpose of the study and gave written informed consent to participate. The study complied with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

Apparatus and Stimuli Two videos of a male basketball player filmed from a front perspective were used. At the beginning of the video, the athlete stood in an initial position with feet parallel, looking straight into the camera and holding the basketball in front of the body. In one video, the basketball player executed a pass without a head fake (i.e., pass direction and head orientation were aligned), and in the other video, he performed a head fake (i.e., pass and head pointed to different directions). The videos were filmed with the basketball player performing natural movements. For the experiments, however, the timing of specific parameters of the movement execution should be comparable between the pass with and without a head fake. To this end, two videos were chosen, in which this was the case (see Figure 6). Both videos have a duration of 760 ms and start with the basketball player standing in the initial position with the ball straight in front of the body. The head turn is initiated directly afterwards and is clearly visible after 160 ms. The basketball player first moves the ball downward and then to the side. While doing so, the ball arrives at the lowest point after 240 ms. At the same time the ball leaves the center. 360 ms after the beginning of the movement, the ball is in front of the player’s chest and his arms start to move forward. The last frame shows the basketball player with extended arms, after the execution of the pass. Both videos were mirrored, so that the pass with and without a head fake could be shown for both sides. The software “Presentation” (version 20.0, Neurobehavioral Systems Inc.,

[6] This calculation of the required sample size also applies for Experiment 2 and 4, which also use a 2 x 2 repeated-measures design.

Berkeley, CA) was used to present the videos randomly and in full screen on a 22" monitor. The keys "4" and "6" in the horizontal condition and the keys "2" and "8" in the vertical condition of the keyboard number pad were used as response buttons.

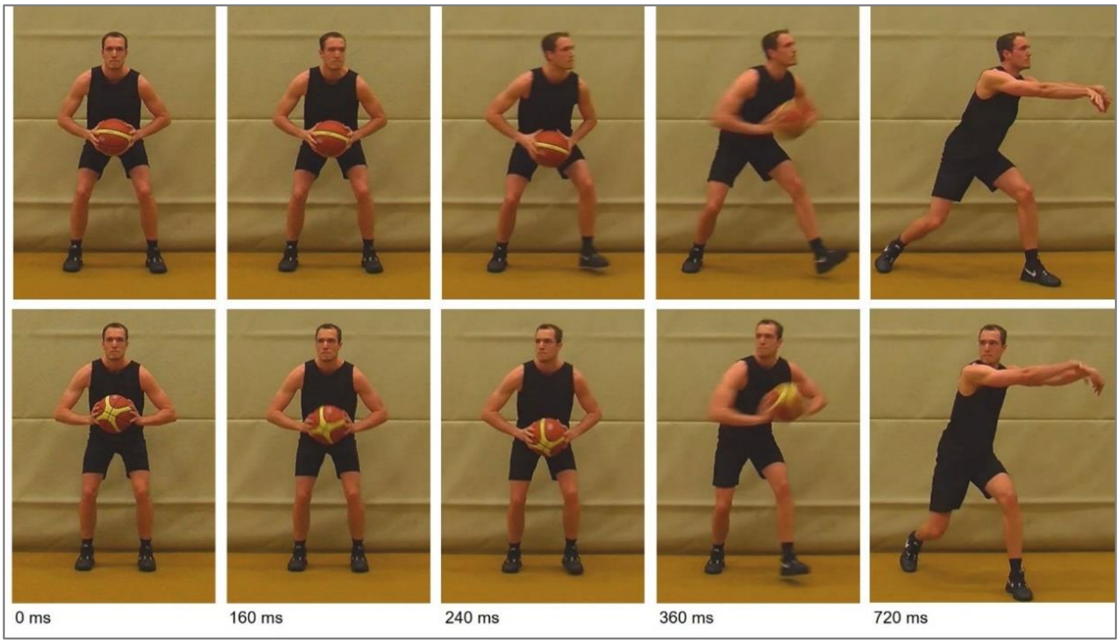

Figure 6. Movement timing. Depicted is the timing of the movement executions for the pass without a head fake (upper row) and the pass with a head fake (bottom row) in the videos used for Experiments 1 – 4.

Procedure Participants sat approximately 60 cm in front of a computer screen and were instructed to indicate the pass direction of the basketball player by pressing one of the two response keys. In the horizontal condition, participants were asked to press the "4" of the number pad for a pass to the left and the "6" for a pass to the right. In the vertical condition, the keys "2" and "8" were used. Half of the participants had to press the "2" for a pass to the left and the "8" for a pass to the right. The other half of the participants were instructed to press the "8" for the pass to the left and the "2" for the pass to the right. In each condition, a pass to the left was indicated with the left index finger and a pass to the right with the right index finger. The key arrangement (horizontal/vertical) was varied blockwise and the order of blocks was counterbalanced across participants.

Each trial consisted of a blank screen (500 ms), a fixation cross (1000 ms), a blank screen (500 ms), and one of the four different videos (760 ms). When a participant committed an error, the word “Fehler” (German word for “error”) was displayed on the screen for 500 ms. The experiment started with 16 practice trials (each video was presented four times) to familiarize the participants with the task. Afterwards, two experimental blocks with 200 trials each were carried out, so that each video was presented 100 times. Between the blocks, participants could take a rest.

Data Analyses Reaction times (RTs) were screened for outliers. Wrong answers (4.5 %) as well as RTs below 100 ms and above 1500 ms (0.04 %) were excluded from RT analysis. Mean reaction times and mean error rates (ERs) were submitted to repeated measures ANOVAs with the within-subject factors *type of pass* (no head fake vs. head fake) and *key arrangement* (horizontal vs. vertical).

2.2.2 Results

Reaction Times Mean reaction times are presented in Figure 7 (lines). The repeated measures ANOVA showed a main effect for the factor type of pass [$F(1, 23) = 346.09$, $p < .001$, $\eta_p^2 = .94$]. Participants reacted slower, when a head fake was presented (542 ms, *SE* = 7 ms) compared to no head fake (477 ms, *SE* = 5 ms). Neither a main effect for the factor key arrangement [$F(1, 23) = 1.07$, $p = .312$, $\eta_p^2 = .04$] nor an interaction between both factors [$F(1, 23) = 0.33$, $p = .572$, $\eta_p^2 = .01$] was found.

Error Rates The repeated measures ANOVA on the mean error rates (see Figure 7, columns) revealed a significant main effect for the factor type of pass [$F(1, 23) = 55.28$, $p < .001$, $\eta_p^2 = .71$]. Participants committed more errors, when a head fake was shown (8 %, *SE* = 1 %) compared to the no head fake condition (1 %, *SE* = 0.2 %). The main effect for the factor key arrangement was not significant [$F(1, 23) = 2.77$, $p = .110$, $\eta_p^2 = .11$]. The main effect for the factor type of pass was qualified by an interaction between both factors [$F(1, 23) = 5.39$, $p = .029$, $\eta_p^2 = .19$]. Post-hoc *t*-tests showed a significant larger head-fake effect in the horizontal (8 %, *SE* = 1 %) than in the vertical condition (6 %, *SE* = 0.9) [$t(23) = 2.32$, $p = .029$, $d = 0.47$].

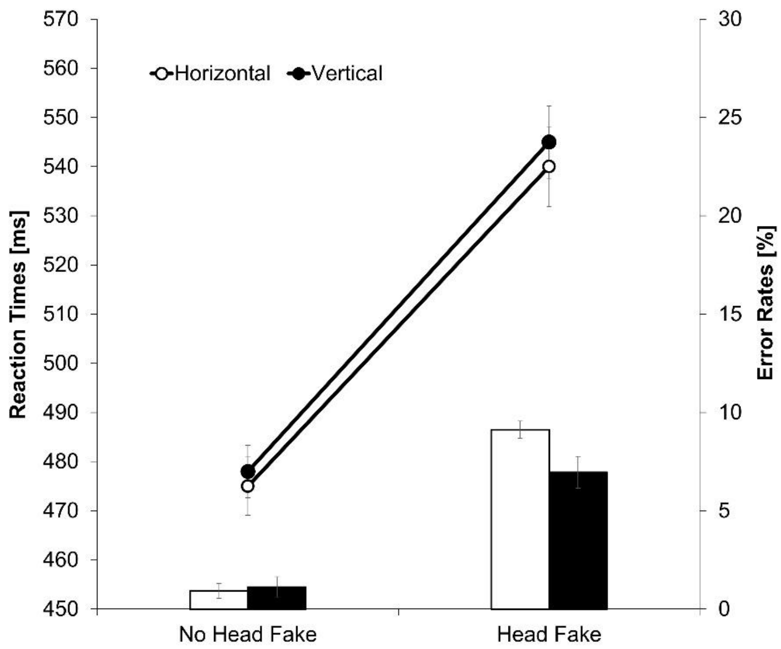

Figure 7. Results of Experiment 1. Mean reaction times (lines) in milliseconds ± standard error (SE) and error rates (columns) in percent ± SE as a function of type of pass (no head fake vs. head fake) and key arrangement (horizontal vs. vertical).

2.2.3 Discussion Experiment 1

The aim of Experiment 1 was to cancel out the dimensional overlap between the irrelevant stimulus feature (head orientation) and the response. To this end, the response key arrangement was changed from horizontal to vertical. As expected, results revealed the typical head-fake effect, that is slower reactions and more errors for passes with a head fake compared to passes without a head fake. Moreover, the head-fake effect in the reaction times did not depend on the key arrangement. Based on the model of dimensional overlap (Kornblum et al., 1990), this result supports the assumption of an S-S interference being responsible for the effect. The result of the error rates is not as clear: The head-fake effect is still present in the vertical condition, pointing to a perceptual origin of the effect. However, the fact that the effect in the vertical condition is smaller than in the horizontal condition contrasts the results of Kunde et al. (2011) and indicates an additional influence of motor activation in the horizontal condition. Thus, it appears that participants' reaction times are not affected by the manipulation, but that they are somewhat more prone to respond with the wrong side (i.e., with the opposite response key) under the horizontal key arrangement. The following three experiments use the additive-factors logic to further examine the locus of the head-fake effect with dynamic stimuli.

2.3 Experiment 2

To further examine if a head fake in basketball influences perceptual or other processes, Experiment 2 used the additive-factors method addressing perceptual processes by manipulating stimulus-related aspects affecting the perceptual encoding of spatial information. With this objective, image quality was reduced in half of the trials. If the head fake affects perceptual processes, an interaction with the factor image quality should be observed. In contrast, two main effects would point to an origin of the head-fake effect, which is not perceptual.

2.3.1 Methods and Materials

Participants Twenty-four participants (12 females, 5 left-handed, M_{age} = 22.3 years, *SD* = 1.8), without any specific expertise in basketball, took part voluntarily in this experiment. All participants reported normal or corrected to normal vision, were naïve with regard to the purpose of the study and gave written informed consent to participate. The experiment was in accordance with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

Apparatus and Stimuli The four videos of Experiment 1 were used in normal and reduced image quality (see Figure 8). As in Kunde et al. (2011), image quality was changed by reducing the brightness by 50 % and the contrast by 10 %. The eight videos were presented on a 22” monitor with the software “Presentation” (version 20.0, Neurobehavioral Systems Inc., Berkeley, CA). In this experiment, the keys “A” and “Ä” of a German keyboard were used as response keys. These keys were aligned horizontally with a distance of approximately 19 cm (from center to center).

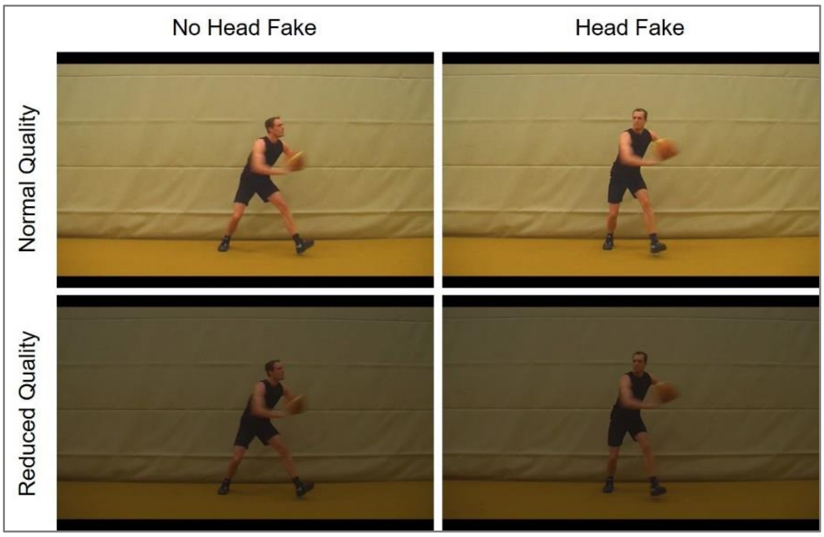

Figure 8. Frames of the videos used in Experiment 2. On the left side, passes without a head fake are presented, and on the right side, head fakes are presented. In the upper row, stimuli with normal image quality are shown, and in the bottom row, stimuli with reduced quality are shown. In the experiment, all four stimuli were also shown with a pass to the left.

Procedure The procedure was similar to Experiment 1. Participants sat approximately 60 cm in front of a computer screen and were instructed to indicate the pass direction of the basketball athlete. The sequence of a trial was as follows: blank screen (500 ms), fixation cross (500 ms), blank screen (500 ms) and one of the four different videos of the normal image quality or of the reduced image quality. In case of an error the word "Fehler" (German word for "error") was presented on the screen for 500 ms. The factor *image quality* was tested blockwise, that is, in one block the videos with normal image quality were used and in another block the videos with reduced image quality were used. The order of blocks was counterbalanced across participants. The experiment started with 16 practice trials (the same image quality like in the first block), in order to familiarize participants with the task. Afterwards, the two experimental blocks with 200 trials each, were carried out. Thus, each video was presented 50 times. Between the blocks, participants could take a rest.

Data Analyses RTs were screened for outliers. Wrong answers (5.2 %) as well as RTs below 100 ms and above 1500 ms (0.1 %) were excluded from RT analysis. Mean RTs and ERs were submitted to repeated measures ANOVAs with the within-subject factors *type of pass* (no head fake vs. head fake) and *image quality* (100 % vs. 50 %).

2.3.2 Results

Reaction Times The repeated measures ANOVA on mean RTs (see Figure 9, lines) showed a significant main effect for type of pass [$F(1, 23) = 489.28$, $p < .001$, $\eta_p^2 = .96$]. Participants responded slower in the head-fake condition (471 ms, $SE = 5$ ms) compared to the no head-fake condition (416 ms, $SE = 5$ ms). There was neither a significant main effect for image quality [$F(1, 23) = 0.1$, $p = .759$, $\eta_p^2 < .01$] nor an interaction between both factors [$F(1, 23) = 3.71$, $p = .067$, $\eta_p^2 = .14$].

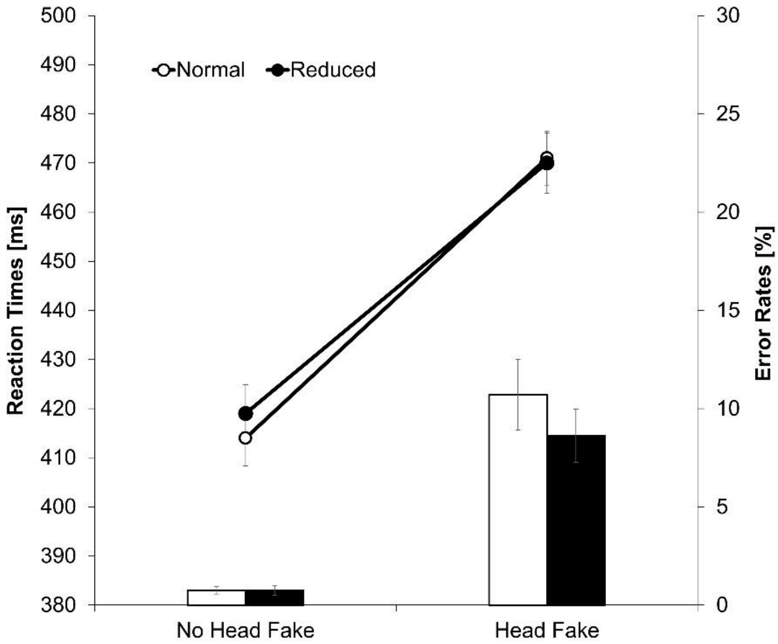

Figure 9. Results of Experiment 2. Mean reaction times (lines) in milliseconds ± SE and error rates (columns) in percent ± SE as a function of type of pass (no head fake vs. head fake) and image quality (100 % vs. 50 %).

Error Rates Mean ERs are presented in Figure 9 (columns). The repeated measures ANOVA revealed a significant main effect for type of pass [$F(1, 23) = 39.69$, $p < .001$, $\eta_p^2 = .63$]. Participants committed more errors in case of a pass with a head fake (10 %, $SE = 1$ %) compared to no head fake (0.75 %, $SE = 0.2$ %). There was neither a significant main effect for image quality [$F(1, 23) = 2.59$, $p = .121$, $\eta_p^2 = .1$] nor an interaction between both factors [$F(1, 23) = 3.39$, $p = .079$, $\eta_p^2 = .13$].

2.3.3 Discussion Experiment 2

In Experiment 2, the image quality of half of the stimuli was reduced in order to achieve a manipulation of perceptual processing. According to the additive-factors logic, two factors should interact with each other, when they influence the same processes, but have an additive effect on reaction times, when they affect different processes (Sternberg, 1969, 2011). As hypothesized, results showed the typical head-fake effect. However, the reduced image quality did not influence reactions at all, even though we adjusted the stimuli in the same way as Kunde et al. (2011) did in their study. It seems plausible that the stimulation on the retina from the motion in dynamic stimuli is more salient compared to that in static stimuli. Therefore, a stronger manipulation of the videos' image quality is needed to influence perceptual processing, which then allows conclusions to be drawn with regard to the additive-factors logic. This was accomplished in Experiment 3.

2.4 Experiment 3

In Experiment 3, the same logic and experimental design as in Experiment 2 was applied. In contrast to Experiment 2, two more manipulations of the image quality were used to finally achieve a manipulation of perceptual processing. From a methodological point of view, this is further in line with Sternberg's approach, who proposed:

> *"When it is possible to define more than two levels of a factor, this should be considered. As well as having other advantages […], multiple levels permit more powerful tests of interaction, and permit focused tests of monotone interaction, the interaction of most interest."* (Sternberg, 2011, p. 201)

2.4.1 Methods and Materials

Participants An *a priori* power analysis using G*Power 3 (Faul et al., 2007) was conducted to calculate the required sample size for this 2 x 4 repeated-measures design. The *f*-value was again adjusted following Rasch et al. (2010; see Experiment 1). This time, the number of repetitions in G*power was set to 4, in order to estimate the required sample size for the interaction. The correlation among repeated measures was again set to the conservative value of 0.3. Results suggest a sample size of at least $N = 17$ (given

$f' = 0.3536$, $\alpha = 0.05$, $1\text{-}\beta = 0.8$) (Faul et al., 2007). Twenty-four participants without any specific expertise in basketball (8 females, 4 left-handed, $M_{\text{age}} = 23.7$ years, $SD = 3.9$) took part voluntarily in this experiment. All participants reported normal or corrected to normal vision, were naïve about the purpose of the study and gave written and informed consent to participate. The study complied with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

Apparatus and Stimuli In total, 16 videos were used. Each of the four videos of Experiment 4 was used in normal and with reduced image quality. For the three adapted image qualities, brightness was reduced to either 50 %, 30 %, or 10 % and, at the same time, contrast was reduced to 40 % (for examples of the 50 % condition, see Figure 8). The experimental setup was identical to Experiment 2.

Procedure The procedure was nearly the same as in Experiment 2. In contrast to Experiment 2, the factor image quality was tested in randomized order[7], to rule out carryover effects between experimental blocks. After 16 practice trials, there were two experimental blocks with 200 trials each. Thus, each video was presented 25 times.

Data Analyses RTs were screened for outliers. Wrong answers (4.5 %) as well as RTs below 100 ms and above 1500 ms (0.1 %) were excluded from RT analysis. Mean RTs and ERs were submitted to repeated measures ANOVAs with the within-subject factors *type of pass* (no head fake vs. head fake) and *image quality* (100 % vs. 50 % vs. 30 % vs. 10 %). If the sphericity assumption was violated, Greenhouse-Geisser corrected values are reported. For multiple comparisons, the alpha value was adjusted according to Bonferroni-Holm and corrected *p*-values are reported.

2.4.2 Results

Reaction Times The repeated measures ANOVA on mean RTs (see Figure 10, lines) revealed a significant main effect for the factor type of pass [$F(1, 23) = 727.91$, *p*

[7] A further analysis of the RTs in Experiment 2 with the additional factor *order of blocks* revealed a significant interaction between type of pass, image quality and order of blocks [$F(1, 22) = 7{,}00$, $p = .015$, $\eta_p^2 = .24$]. When participants started with normal image quality, the head-fake effect in the reduced image quality condition was smaller (46 ms) than when participants started with this condition (57 ms) [$t(22) = 7.11$, $p = .012$, $d = 1.22$].

< .001, η_p^2 = .97] as well as for the factor image quality [F(1.60, 36.86) = 55.28, p < .001, η_p^2 = .84]. The main effects were qualified by a significant interaction between both factors [F(1.91, 43.87) = 727.91, p < .001, η_p^2 = .72]. Post-hoc t-tests were used to compare the head-fake effect between the different image qualities. The head-fake effect was significantly larger with normal image quality (69 ms, SE = 3 ms) than with 30 % quality (53 ms, SE = 3 ms) [t(23) = 5.88, p < .001, d = 1.20] and also larger than with 10 % image quality (31 ms, SE = 3 ms) [t(23) = 5.40, p < .001, d = 1.72]. Moreover, the head-fake effect with 50 % image quality (69 ms, SE = 3 ms) was larger than with 30 % quality [t(23) = 7.11, p < .001, d = 1.45] and also than with 10 % [t(23) = 9.66, p < .001, d = 1.97]. Finally, the difference between 30 % and 10 % image quality was also significant [t(23) = 5.98, p < .001, d = 1.22]. The head-fake effect in the normal image quality and the 50 % reduced quality did not differ significantly (p = .989).

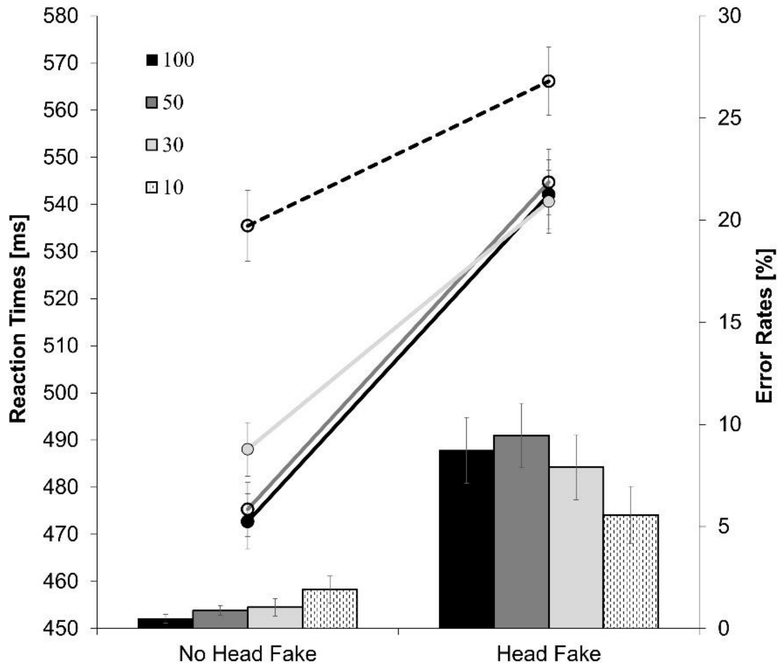

Figure 10. Results of Experiment 3. Mean reaction times (lines) in milliseconds ± SE and error rates (columns) in percent ± SE as a function of type of pass (no head fake vs. head fake) and image quality (100 % vs. 50 % vs. 30 % vs. 10 %).

Error Rates The repeated measures ANOVA on mean ERs (see Figure 10, columns) revealed a significant main effect for the factor type of pass [F(1, 23) = 29.20, p < .001, η_p^2 = .56]. Participants committed more errors when a pass with a head fake

(8 %, *SE* = 1 %) was shown compared to a pass without a head fake (1 %, *SE* = 0.2 %). The main effect of the factor image quality was not significant [$F(3, 69) = 1.83$, $p = .150$, $\eta_p^2 = .07$]. Moreover, the interaction between the factors type of pass and image quality was significant [$F(3, 69) = 6.64$, $p = .001$, $\eta_p^2 = .22$]. Post-hoc *t*-tests for comparisons of the head-fake effect in the different image qualities were carried out. Results showed significant differences in the head-fake effect between normal (8 %, *SE* = 2 %) and 10 % image quality (4 %, *SE* = 1 %) [$t(23) = 3.23$, $p = .02$, $d = 0.66$] as well as between 50 % (9 %, *SE* = 2 %) and 10 % image quality [$t(23) = 3.95$, $p = .006$, $d = 0.81$]. The other single comparisons were not significant ($ps \geq .092$).

2.4.3 Discussion Experiment 3

Experiment 3 was conducted to examine if the head-fake effect interacts with a perceptual manipulation of the stimuli. In extension to Experiment 2, two stronger manipulations of image quality were used. Overall, the head-fake effect in the reaction times was present with all image qualities, but the size of the effect depended on the image quality. The more the image quality was reduced, the smaller was the head-fake effect. Only the difference between the normal and the 50 % reduced image quality was not significant, which is in line with the findings of Experiment 2. The results of the error rates also revealed an interaction between type of pass and image quality with the same pattern. Despite the presence of an interaction effect between both factors, the results are not in accordance with the findings of Kunde et al. (2011). In their experiment with static images, a reduced image quality led to a much larger head-fake effect as compared to normal image quality. This difference in results suggests that there might be a difference between the head-fake effect in dependence of the stimulus used (static vs. dynamic presentation). Based on the additive-factors method (Sternberg, 1969, 2011), however, an interaction of two factors can be interpreted as both factors influencing the same process, in this case a perceptual process (as signified by the monotone interaction based on the systematic and multi-level variation of image quality). According to Sternberg (1969, 2011), the interaction tells us that two factors affect the same process, but – and this is important to note – it does not exclude that these factors also influence other processes independently from each other. Therefore, Experiment 4 was conducted to examine, if the head fake with dynamic stimuli additionally affects response selection processes.

2.5 Experiment 4

The results of the previously described experiments suggest that the head-fake effect with dynamic stimuli is based on a perceptual interference between head orientation and pass direction. However, to further examine the potential (additional) influence of stimulus-related aspects on response-selection processes, the additive-factors method (Sternberg, 1969) was again applied in Experiment 4. This was accomplished by using a Simon task, in which participants were instructed to respond to the color of the ball instead of the pass direction. In contrast to Experiment 1, the match/mismatch between stimulus and response was manipulated by changing stimulus-related aspects of the task (i.e., the color of the ball). According to the additive-factors logic (Sternberg, 1969), the following assumption can be made: If the head fake also influences response-selection processes, results should reveal an interaction between type of pass and S-R congruency.

2.5.1 Methods and Materials

Participants Twenty-five participants without any specific expertise in basketball took part voluntarily in this experiment. After excluding one participant due to technical problems, the data of 24 participants (11 females, 4 left-handed, M_{age} = 23.4, SD = 4.3) were analyzed. All participants reported normal or corrected to normal vision and were naïve with regard to the purpose of the experiment. Each participant gave written informed consent to participate in this study. The study was realized in accordance with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

Apparatus and Stimuli The same videos like in Experiment 1 were used. In this experiment, each of these four videos were used two times, with the color of the basketball changing either to blue or to yellow during the pass (280 ms after video onset). The stimulus-response assignments can be seen in Figure 11. The software

“Presentation” (version 20.0, Neurobehavioral Systems Inc., Berkeley, CA) was used to present the videos randomly and in full screen on a 22” monitor. The keys “A” and “Ä” of a German keyboard were used as response keys. In stimulus-response (S-R) congruent conditions, the required response (specified by the color of the ball) was on the same side as the basketball, whereas in S-R incongruent conditions, the required response was on the opposite side.

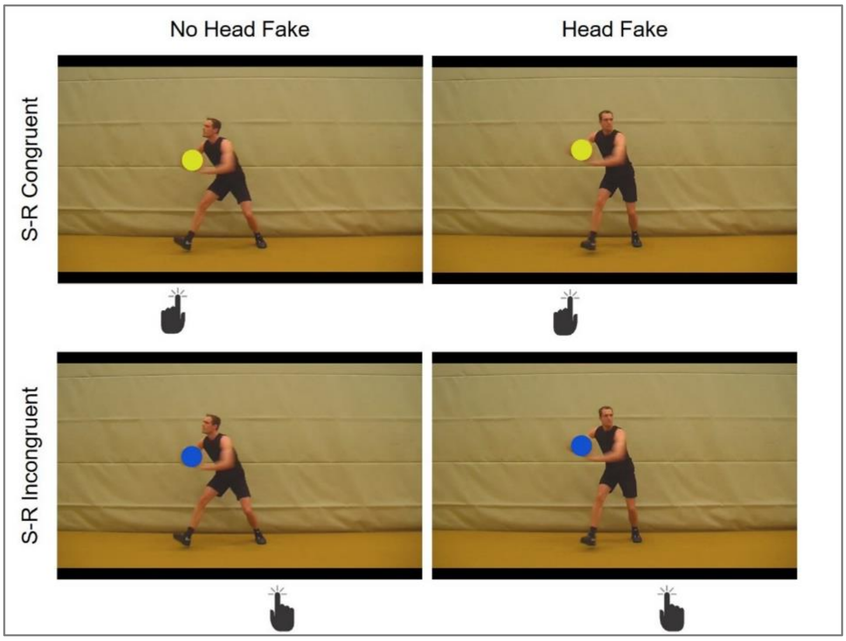

Figure 11. Stimuli-response assignments in Experiment 4, exemplary shown for a left response to the yellow ball and a right response to the blue ball. In the experiment, all four videos were also shown with a pass to the right.

Procedure Participants sat approximately 60 cm in front of a computer screen and were instructed to indicate the color of the ball (blue or yellow) by pressing one of two response buttons. The S-R assignment was counterbalanced across participants. One trial consisted of a blank screen (500 ms), a fixation cross (1000 ms), a blank screen (500 ms) and one of the eight different videos (760 ms). When a participant committed an error, the word “Fehler” (German word for “error”) was displayed on the screen for 500 ms. The experiment started with 16 practice trials (each video was presented two times) to familiarize the participants with the task. Afterwards, two experimental blocks with 200 trials each were carried out, so that each video was presented 50 times. Between the blocks, participants could take a rest.

Data Analyses RTs were screened for outliers. Wrong answers (6.9 %) as well as RTs below 100 and above 1500 ms (0.3 %) were excluded from RT analyses. Mean RTs and mean ERs were submitted to repeated measures ANOVAs with the within-subject factors *type of pass* (no head fake vs. head fake) and *S-R congruency* (S-R congruent vs. S-R incongruent).

2.5.2 Results

Reaction Times The repeated measures ANOVA on mean RTs (see Figure 12, lines) revealed a significant main effect for the factor type of pass [$F(1, 23) = 16.33$, $p = .001$, $\eta_p^2 = .42$]. Participants reacted faster, when a pass without a head fake was displayed (658 ms, *SE* = 8 ms) compared to a pass with a head fake (664 ms, *SE* = 9 ms). For the factor S-R congruency, no significant main effect was found [$F(1, 23) = 0.63$, $p = .434$, $\eta_p^2 = .03$]. The interaction between both factors was significant [$F(1, 23) = 38.34$, $p < .001$, $\eta_p^2 = .42$]. Post-hoc paired *t*-tests were carried out to compare the reaction times between conditions. The two fastest conditions “no head fake with congruent S-R mapping” (651 ms, *SE* = 8 ms) and “head fake with incongruent S-R mapping” (655 ms, *SE* = 9 ms) did not differ significantly from each other ($p = .58$). That means, responses were equally fast, independently of the position of the relevant stimulus feature (i.e., colored ball) for as long as the head was on the same side as the response. All other single comparisons reached significance. This became evident in shorter reaction times for “no head fake with congruent S-R mapping” compared to “no head fake with incongruent S-R mapping” (666 ms, *SE* = 8 ms) [$t(23) = 5.69$, $p < .001$, $d = 1.16$] and also compared to “head fake with congruent S-R mapping” (673 ms, *SE* = 8 ms) [$t(23) = 7.70$, $p < .001$, $d = 1.57$]. In short, this shows that reactions were faster when head, ball, and response were on the same side compared to the two conditions, in which the head was on the other side as the response. Moreover, reaction times were shorter for “head fake with incongruent S-R mapping” compared to “no head fake with incongruent S-R mapping” [$t(23) = -3.31$, $p = .009$, $d = 0.68$] and also compared to “head fake with congruent S-R mapping” [$t(23) = -4.79$, $p < .001$, $d = 0.98$]. This means that reactions were faster when head and response were on the same side, but the relevant stimulus feature (i.e., ball) on the other side compared to conditions in which the head was on the other side as the response (independently of the position of the ball).

The slowest reactions were observed for “head fake with congruent S-R mapping”, which were slower compared to “no head fake with incongruent S-R mapping” [$t(23) = 3.02$, $p = .012$, $d = 0.62$]. In both conditions, the head is on the other side as compared to the response, but reactions are slower, when there is a head fake (i.e., relevant stimulus is on the same side as the response), compared to no head fake (i.e., relevant stimulus is on the other side as the response).

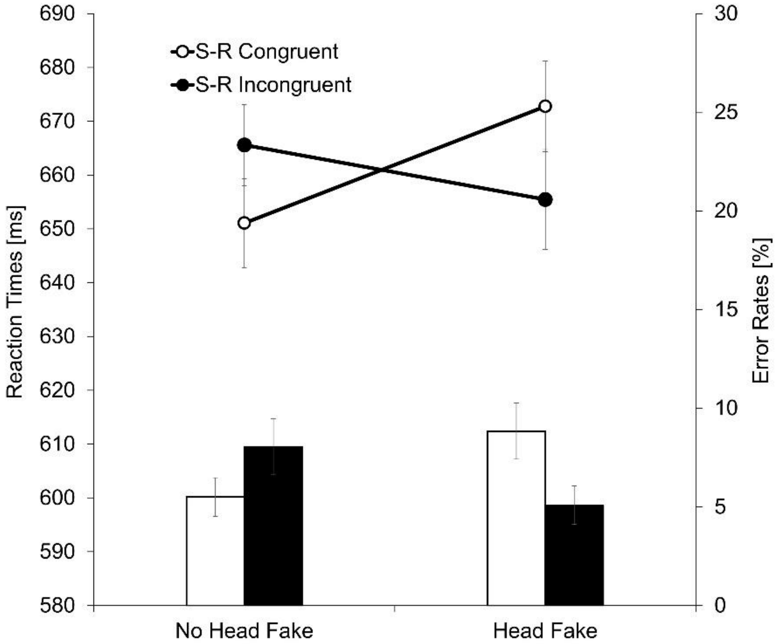

Figure 12. Results of Experiment 4. Mean reaction times (lines) in milliseconds ± standard error (SE) and error rates (columns) in percent ± SE as a function of type of pass (no head fake vs. head fake) and spatial congruency (S-R congruent vs. S-R incongruent).

Error Rates Mean error rates (see Figure 12, columns) were also submitted to a repeated measures ANOVA. Results showed no significant main effect, neither for the factor type of pass [$F(1, 23) = 0.11$, $p = .748$, $\eta_p^2 = .01$] nor for the factor S-R congruency [$F(1, 23) = 0.94$, $p = .343$, $\eta_p^2 = .04$]. The interaction between both factors was significant [$F(1, 23) = 9.04$, $p = .006$, $\eta_p^2 = .28$). Post-hoc paired *t*-tests revealed significantly more errors for head fakes with a congruent S-R mapping (9 %, *SE* = 1 %) compared to passes without a head fake and a congruent S-R mapping (6 %, *SE* = 1 %), $t(23) = 3.70$, $p = .006$, $d = 0.75$, and also compared to head fakes with an incongruent S-R mapping (5 %, *SE* = 1 %), $t(23) = 2.81$, $p = .05$, $d = 0.57$. No other single comparison was significant (all ps $\geq .2$).

2.5.3 Discussion Experiment 4

In this experiment, the basketball stimuli were combined with a Simon-task (reaction to the color of the ball) to manipulate response-selection processes. First, the results of the reaction times exhibit the typical head-fake effect, even though the effect is very small. This might be due to the fact that neither the head orientation nor the pass direction was relevant for the task. For this reason, it is especially interesting that the irrelevant directional information had an effect at all. In this regard, other individuals' directional information (e.g., head turn) seems to be important as social cues, which provide information about other individuals' attention (Langton & Bruce, 1999, 2000; Weigelt et al., 2020). In contrast to Kunde et al. (2011), there was no S-R congruency effect on its own, which means that neither the reaction times nor the error rates were influenced by the position of the relevant stimulus feature (i.e., colored ball) alone. However, the type of pass (no head fake vs. head fake) interacted with the S-R congruency. This result allows conclusions to be drawn about the origin of the head-fake effect. In case of a solely perceptual locus of the head-fake effect, the reaction times should have been largest in the condition, which combined a head fake with an incongruent S-R mapping (i.e., head and response on the same side, but ball on the other side). This is because the time to solve the perceptual conflict would have been additive to the extra time needed for S-R incongruent stimuli. However, this was not the case. The results even showed the contrary: Reaction times in this condition were equally fast as in the condition, in which response, colored ball, and head were on the same side. This is interesting, since the response key in this condition, which combined a head fake with an incongruent S-R mapping, does not match the side of the relevant feature (colored ball), but the side indicated by the head orientation. This result points to a special role of the head orientation (see also Weigelt et al., 2020). It was further supported by the fact that the slowest responses were observed, when the relevant stimulus feature (i.e., colored ball) and the response were on the same side, but the head was turned to the other side. Moreover, as compared to the other conditions, participants showed medium reaction times when the head and ball were on the same side, but responses were given on the other side the ball and the head were pointing to. In sum, the results show larger RTs when the head was not on the same side as the response, pointing to an S-R interference caused by a mismatch of head orientation and response. However, it seems that an S-S interference had an additional effect on reaction times, a pattern of results, which can already be predicted from Sternberg's additive-factors logic (see Figure 2 in Sternberg, 1969). This becomes clear when comparing the condition in which the ball and the head were on the same side, but the response key on the other side with the condition in which a head fake was shown combined with a S-R congruent answer. If the effect would be solely based on S-R interference between head orientation and response, these two conditions should lead to an effect of the same size, since in both conditions, the head is on the contrary side as compared to the answer. However, the effect was larger, when the mismatch of head orientation and response side was accompanied by a pass to the other side (i.e., head fake), which points to the S-S interference effect.

It is important to note that Kunde et al. (2011) used static images of a basketball player and thus, presented directional (i.e., head orientation and pass direction) and color features (i.e., color of the ball) at the same time. In this experiment, these features were not presented simultaneously, but the color information was only presented during the pass execution (280 ms after video onset). If the ball in the video had been colored before pass initiation, then there could not have been any additional head-fake effect on the responses to the color stimulus, because the basketball player was standing in an initial position and no directional information was present at that time (in terms of neither pass direction nor head orientation). Likewise, if the color information had been presented earlier (i.e., between pass initiation and 280 ms into pass execution), then it is still possible that the head-fake effect would not have additionally affected the responses to the color stimulus. This is possible (1) because color information is being processed faster than motion information (Arnold et al., 2001) and (2) because of the irrelevance of directional information for the Simon-like task.

2.6 Discussion Experiment 1-4

The present study aimed to identify the origin of the head-fake effect in basketball with dynamic stimuli. Within the chain of different information processes, different mechanisms are conceivable causing the effect. First, the different head and pass orientation during a head fake could interfere during perceptual processing, so that the problem which of this information is relevant must be solved initially, before the directional information can be further processed. This would result in a longer reaction time in case of a pass with a head fake compared to a pass, which does not contain different directional information (Kunde et al., 2011). Second, the head turn could cause a conflict after perceptual processing, that is, the head could be connected with a corresponding response, and both could interfere during response selection. If the conflict is not solved before or during response selection, the head turn could even lead to a response activation and a corresponding motor response (Polzien et al., 2021; Schütz et al., 2020).

Previous research has shown a perceptual origin of the head-fake effect for static stimuli (Kunde et al., 2011), evidence for response activation with apparent motion (Polzien et al., 2021), and a motor activation in a subliminal priming paradigm with static images (Schütz et al., 2020). Therefore, the question arises, if the head-fake effect with dynamic stimuli is based on a perceptual conflict and/or on a conflict that arises later during information processing. This question was addressed in the present study. To this end, four experiments with videos of a basketball player playing a pass either with or without a head fake, were conducted. In Experiments 1 to 3, participants were instructed to respond to the pass direction of the basketball player. In Experiment 1, the dimensional overlap between the irrelevant stimulus feature (i.e., head orientation) and the response was removed by changing the arrangement of the response keys from horizontal to vertical. The head-fake effect in the reaction times with both response key arrangements was of the same size, pointing to perceptual interference as causing the effect. However, the head-fake effect in the error rates was reduced with vertical as compared to horizontal response keys. This suggests that an additional influence of motor activation might have contributed to the size of the effect.

To further examine this potential influence of different processes, the additive-factors method (Sternberg, 1969) was applied in Experiments 2 to 4. This method is based on a view of an information processing system with separate processes. It is assumed that two factors have an additive effect, when they have an influence on different processes, whereas an interaction effect is obtained, when these factors influence the same process (Sternberg, 1969, 2011). In Experiments 2 and 3, the image quality of the videos was manipulated to influence perceptual processing. The head-fake effect depended on image quality, pointing to perceptual interference during the head fake. This finding of an interaction effect in general was in accordance with the results by Kunde et al. (2011), who applied this logic to static images. Beyond that, the head-fake effect in the present study was reduced the more the image quality was reduced. In contrast, Kunde et al. (2011) found an increased head-fake effect with reduced stimulus quality. To examine if this difference in results was caused by an additional interference during later phases of information processing, Experiment 4 was conducted. In this experiment, a manipulation of response-selection processes was induced through a Simon task. Participants were no more instructed to respond to the pass direction, but to the color of the ball, which changed either to blue or to yellow. Results revealed an interaction effect, which, according to additive-factors logic, supports the assumption of response selection being involved in the head-fake effect. Moreover, the results in the different conditions in Experiment 4 point to an additional perceptual influence.

In sum, the results of the present study support the assumption of different stimulus modalities causing the head-fake effect in basketball based on different perceptual-cognitive mechanisms (Polzien et al., 2021). Kunde et al. (2011) found a clearly perceptual origin of the head-fake effect with static stimuli. This perceptual influence was also observed in the present study with dynamic stimuli. However, the reduced error rates in Experiment 1 imply additional interference effects during later processes. Most importantly, Experiment 4 shows a strong influence of the irrelevant head orientation on reaction times. This is on the one hand based on an incongruence between head orientation and response side (response-selection process), but on the other hand, there is an additional influence based on an incongruence between head orientation and pass direction (perceptual process).

An explanation for differences with static compared to dynamic stimuli offers the theory of common coding (Prinz, 1990, 1997). According to this theory, the observation of an action activates the same action representation as the self-execution of the same action. This activation could be used for action simulation (Jeannerod, 2001), which itself could be relevant for action anticipation. Results in this regard suggest that static images as well as videos of an action can activate a response in the observer with the same effector, which is acting in the image/video (Bach et al., 2007; Brass et al., 2000;

Gillmeister et al., 2008). However, static images only seem to activate the response, when the attention is drawn to the effector in the image (Bach & Tipper, 2007; Polzien et al., 2019). Accordingly, the task-irrelevant and to-be-ignored stimulus feature head orientation in the study of Kunde et al. (2011) did not activate any action representations. Videos of an action, in contrast, can activate the response on their own, that is, without explicitly drawing attention to specific stimulus features (Brass et al., 2000). This might be the reason why head orientation in the present study did not only influence perceptual processes. Considering a model of information processing with successive processes or stages (Sanders, 1990), the conflict, which is observed with static images, seems to take place at a very early point in time of perceptual processing. Specifically, the conflicting information of head orientation could lead to a prolonged process of feature extraction. For static images, this conflict seems to be solved before the neural activation based on common coding takes place in a later phase (e.g., during feature identification). For video sequences, the perceptual conflict cannot as easily be solved as for static images, as there is a flow of new incoming conflicting information, which must be permanently updated, even during later phases of information processing (i.e., response selection). Accordingly, for video sequences, head orientation can both cause interference effects during perceptual processes and also during response selection or even later processes. The common-coding mechanism is responsible for the conflict emerging during response selection (or later): The head orientation during a head fake first activates a pattern, which is associated with a pass to the corresponding side. Afterwards the ball activates a pattern, which is associated with a pass to the corresponding (other) side. The resulting conflict between both activations must be solved during the following information processing, for example during response selection. If the conflict is not already solved during response selection, the activation of the action representation might also trigger a motor response, as found by Schütz et al. (2020). Therefore, it is possible that static images only trigger a conflict during “pure” perceptual processes affecting the initial phase of information processing, but that dynamic stimuli provoke additional conflict during later phases of information processing.

Finally, the results of the present study are interesting from a theoretical as well as a methodological perspective, since they suggest that the more complex the stimulus is, the more complex is the information processing and the more potential sources of interference arise. These sources of interference might influence reactions independently from each other and in combination cause a larger effect. The world around us is complex and always in motion. Therefore, it seems necessary to examine interference effects not only with static images, but also with more complex and more realistic stimuli. Furthermore, future studies on the head-fake effect should examine if dynamic stimuli (apparent motion, videos) not only lead to interference during response-selection processes, but also induce a motor activation, when the response mode is more complex (i.e., full body movement).

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A question of (perfect) timing: A preceding head turn increases the head-fake effect in basketball

Chapter 3

Abstract In many kinds of sports, deceptive actions are frequently used to hamper the anticipation of an opponent. The head fake in basketball is often applied to deceive an observer regarding the direction of a pass. To perform a head fake, a basketball player turns the head in one direction, but passes the ball to the opposite direction. Several studies showed that reactions to passes with head fakes are slower and more error-prone than to passes without head fakes (head-fake effect). The aim of a basketball player is to produce a head-fake effect for as large as possible in the opponent. The question if the timing of the deceptive action influences the size of the head-fake effect has not yet been examined systematically. The present study investigated if the head-fake effect depends on the temporal lag between the head turn and the passing movement. To this end, the stimulus onset asynchrony between head turn, and pass was varied between 0 and 800 ms. The results showed the largest effect when the head turn precedes the pass by 300 ms. This result can be explained better by facilitating the processing of passes without a head fake than by making it more difficult to process passes with a head fake. This result is discussed regarding practical implications and conclusions about the underlying mechanism of the head-fake effect in basketball are drawn.

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Author contributions:

AP, IG, and MW conceived the study. AP was in charge of overall direction and planning of the experiments. AP analyzed the data. AP wrote the manuscript with helpful input from IG and MW.

3.1 Introduction

The ability to anticipate the forthcoming actions of others is crucial in many competitive sports, in which athletes predict the actions of team members and/or opponents under high time pressure. Action anticipation in sports, however, can be hampered by the deliberate use of deceptive actions (for a review on deceptive actions in sports, see Güldenpenning et al., 2017). Following Jackson and colleagues (Jackson et al., 2006), deceptive actions can be distinguished into two categories: actions with the aim to disguise true intentions and those with the aim to deceive the opponent. The former refers to the minimization of that kind of movement information, which is helpful to predict a particular action. In martial arts, for example, a roundhouse kick is often performed for as long as possible like a front kick, so that it becomes difficult for an opponent to identify the type of the kick (Güldenpenning et al., 2015). The latter refers to the use of misleading information. The head fake in basketball is a paradigmatic example for such a deceptive action in which action-relevant and action-irrelevant information are presented (almost) simultaneously, in order to deceive the opponent about the actors' true action intention. That is, during the execution of the head fake, a basketball player turns the head to one side and passes the ball to the opposite side. Thereby, the aim of a basketball player is to deceive the opponent about the throwing direction, so that the pass to a team member can be completed successfully. Several studies showed that participants react slower and more error-prone to the direction of a pass with a head fake compared to a pass without a head fake, signifying the so-called *head-fake effect* (Güldenpenning et al., 2018; Güldenpenning, Schütz, et al., 2020; Kunde et al., 2011).

The impact of the head-fake effect seems to rely on the automatic processing of the head orientation of the player, which cannot be suppressed (Kunde et al., 2011). A recent study shows that the head-fake effect is based on the automatic processing of the head orientation, but not on the (otherwise socially important) gaze information (Weigelt et al., 2020). In contrast to our earlier studies (e.g., Güldenpenning et al., 2018; Kunde et al., 2011), we now refer to head orientation instead of gaze direction as task-irrelevant, interfering stimulus feature. The head-fake effect in basketball has proven to be very robust and can even be observed after extensive practice (Güldenpenning, Schütz, et al., 2020), and in high-level basketball experts (Weigelt et al., 2017).

Moreover, the head-fake effect has been found with static as well as dynamic images and with simple (i.e., keypress) as well as complex (i.e., whole body movement) responses (Alhaj Ahmad Alaboud et al., 2016). There are some further aspects, which have an impact on the size of the head-fake effect: The head-fake effect is reduced, when the working memory of participants is taxed by another task in a dual-task scenario (e.g., counting backwards by three) (Güldenpenning, Kunde, & Weigelt, 2020). Anodal transcranial direct current stimulation (tDCS) over the dorsolateral prefrontal cortex (DLPFC) also reduces the head-fake effect, but not catodal stimulation (Friehs et al., 2020). Furthermore, the frequency with which the head fake is being presented modulates the head-fake effect in the way that the effect decreases the more often the head fake is used (Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018). This aspect is of high practical relevance for real-sport scenarios.

Certainly, when a basketball player uses a head fake, his/her aim is to produce a head-fake effect for as large as possible in the opponent. In this context, an interesting aspect for real sports scenarios, which has not been systematically investigated so far, is the timing of the deceptive action (i.e., the temporal sequencing of movement parts or the whole movement). For the head fake in basketball, the (optimal) temporal lag between the head turn and the pass initiation may be a critical parameter for the success of the deception. Thereby, the question is, if different temporal lags between head turn and pass initiation produce head-fake effects of different magnitudes. To answer this question, the present study made use of the Posner Cueing paradigm (Posner, 1980; Posner et al., 1978).

In cueing experiments, participants are instructed to respond to a target, which is preceded by a cue. The cue signals the location where the target stimulus is presented with a certain probability. The standard finding for non-informative cues is, that responses to targets at cued locations are faster and less error-prone than to targets at uncued locations (Posner et al., 1978). Spatial cueing has often been examined with non-social cues (Hommel et al., 2001; Tipples, 2002). For some time, however, the spatial cueing paradigm has also been used to investigate the influence of another person's head or gaze orientation (both representing strong social cues) on the processing of a subsequent, peripherally presented target (Driver et al., 1999; Slessor et al., 2019).

The time course of the cueing process is often investigated by varying the stimulus onset asynchrony (SOA) between the presentation of the social cue and the target. Friesen and Kingstone (1998), for example, used simple line drawings of a face to examine the effect of gaze orientation on responses to a target letter. To this end, the centrally presented face was first shown with blank eyes. After 680 ms the eyes were filled with pupils (cue) either looking straight ahead or to the left or the right side. After the SOA of 105 ms, 300 ms, 600 ms, or 1005 ms, the target letter was presented to the left or right side of the face, while the face and pupils remained on the screen. Participants were informed that the gaze direction was not predictive for the target location. In a localization task, participants were instructed to indicate the side on which the target appeared for as fast and accurately as possible. Results revealed better performance in cued as compared to un-cued conditions for every SOA up to 600 ms, signifying a gaze-cueing effect. For the SOA of 1005 ms, the gaze-cueing effect was gone. Thus, the gaze-cueing effect emerged rapidly (i.e., for an SOA of 105 ms), and was present for only a relatively short time period (i.e., it disappeared by 1005 ms) (Friesen & Kingstone, 1998; for similar findings see Greene et al., 2009).

Using non-predictive social and non-social cues, Langdon and Smith (2005) presented either a head turned to the left or right (social cue head orientation), a head looking straight ahead with gaze oriented to the left or to the right (social cue gaze orientation), and arrows pointing to the left or right (non-social cue arrow orientation). Moreover, neutral cues were used, which contained no directional information. Before the cue, a pre-cue, which also contained no directional information was presented. Pre-cue and cue were displayed in the center of the screen, and after a variable SOA, an asterisk (target) was presented on the left or right side of the cue. Participants were instructed to respond to the onset of the target. For social cues, no cueing effect was observed at the shortest SOA of 100 ms, but significant head- and gaze-cueing effects were observed for SOAs between 200 ms and 800 ms (Langdon & Smith, 2005, Exp. 1 and 2). However, the results for the SOA 800 ms were ambiguous. In Experiment 6, SOAs between 200 ms and 1200 ms were used and no cueing effects for social cues (gaze cues) could be observed for SOA longer than 600 ms. Interestingly, the authors conducted a cost-benefit analysis to examine the relative contribution of visual attention shifts, and non-attentional automatic priming. This analysis was grounded on the assumption that automatic priming leads to faciliatory effects and emerge faster compared to costs, which are caused by attentional shifts. Langdon and Smith (2005) concluded that gaze cues triggered priming effects at the SOA 200, whereas additional costs of attention shifts could be observed with SOAs of 300 ms or longer. Moreover, the authors found no reduction in the congruency effects between SOA 400, 600, and 800 (Exp. 2).

These results from cueing studies imply that social cues (e.g., gaze direction, head orientation) might modulate the processing of a subsequent target depending on the lag between both stimuli. Accordingly, the aim of the present study is to examine the optimal temporal lag between the head turn and pass initiation for the head-fake effect in basketball. To this end, a cueing experiment with static images of a basketball player with novice participants was conducted. The SOA varied between 0 and 800 ms (in steps of 100 ms) between head turn (i.e., cue; left vs. right) and passing movement (i.e., target; pass with or without head fake to the left or to the right). Targets depicting a pass with a head fake and without a head fake occurred equally often. The head orientation in the cue always matched the head orientation in the target, and thus, was not predictive for the pass direction. Participants were asked to indicate the pass direction by pressing one of two different keys on a computer keyboard.

It is important to note here that this experimental design involves a change in the head-fake paradigm exploited and therefore, is somewhat different from our previous studies on the head-fake effect (Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011). These previous studies revealed a perceptual origin of the head-fake effect when head turn and passing action are presented simultaneously. In this case, the different directional information conveyed by the head turn (task-irrelevant cue) and the passing action (task-relevant cue) cause a conflict, which must be solved before the task-relevant stimulus feature (i.e., pass direction) can be further processed (Kunde et al., 2011). If the cue (i.e., preceding head turn) in the present study does not trigger any additional processes, this effect of perceptual interference should nevertheless be observable and produce a head-fake effect, which is comparable to our previous studies. However, based on the study by Langdon and Smith (2005) mentioned above, we assume the preceding head turn (i.e., task-irrelevant cue) to modulate the head-fake effect in the following manner: The previously presented head turn initially activates the corresponding response. If a target without a head fake occurs, the primed response could immediately be executed, which results in fast reactions in the congruent condition. If, however, a target with a head fake occurs, the (wrong) primed response needs to be cancelled before the correct response can be initiated. Referring to Langdon and Smith (2005), these non-attentional priming effects should emerge with an SOA of 200 ms seconds. For an SOA 300 and larger, additional effects of an attention shift to the side, which is indicated by the head turn should come into play. If the subsequently presented target contains no head fake, the attention is already on the right side and the pass direction can be processed directly. If a target with a head fake occurs, the attention is on the wrong side and must be re-oriented to the other side, before the (task-relevant) pass direction can be processed. Those cueing and priming effects caused by the head turn should be reduced or even eliminated at SOA 800 (Langdon & Smith, 2005).

As mentioned above, our previous studies have shown that the head-fake effect is very robust and only marginally decreases with extensive practice (Güldenpenning, Schütz, et al., 2020). Even expert basketball players cannot inhibit the processing of the head fake and are in general similarly affected by the deception like novices (Weigelt et al., 2017). At the same time, when running a larger research program to investigate deceptive actions in sports over an extended period of time, experts become a rare test population and we refrain from testing experts for as long as we do not see the immediate need arising from the research question. We think that the time-course of the cueing/compatibility effects in novices might similarly shed light on the underlying mechanisms of the head-fake effect and provides relevant information for optimal performance in basketball.

3.2 Experiment 5

3.2.1 Methods and Materials

Participants An *a priori* sample-size analysis using G*Power 3 (Faul et al., 2007) was conducted to determine the required sample size. For the interaction in our 2 x 9 repeated measures design, results suggested a sample size of at least $N = 16$ participants (given $f = 0.25$, $\alpha = 0.05$, $1\text{-}\beta = 0.9$). In total, twenty-six participants took part in the experiment. One participant was excluded due to basketball experience and one due to technical problems. Moreover, one participant was excluded due to high error rates. The remaining twenty-three participants (11 females, 2 left-handed, $M_{age} = 24.1$ years, $SD = 2.1$) had no special expertise in basketball. Participants reported normal or corrected to normal vision and were naïve with regard to the purpose of the study. Each participant gave written informed consent before the experiment. Participants took part voluntarily and did not receive course credits or financial reward. The study was conducted in accordance with the seventh revision (Fortaleza) of the 1964 Declaration of Helsinki by the World Medical Association (WMA). Moreover, this research was reviewed and approved by the Ethics Committee of Paderborn University.

Apparatus and stimuli The stimulus-set consisted of seven static images of a male basketball player, who was photographed from a front perspective. In one picture, the athlete stood in an initial position, head facing the camera and a basketball in front of the body. In two images, the head was turned to the left or the right, respectively, but the basketball was still in front of the body. In addition, there were four pictures (see Figure 13), in which the head and the arms with the ball were turned to the side as if the athlete would execute a pass. These stimuli served as targets and were either congruent (i.e., head and pass to the same side) or incongruent (i.e., head and pass to different sides). The stimuli had a size of 24 x 19.5 cm (2553 x 2069 pixels) and were displayed on a 22” monitor. For presentation of the stimuli, the software “Presentation” (version 20.0, Neurobehavioral Systems) was used. As response buttons, the keys “a” and “ä” of a German keyboard were used for responses with the index finger of the left and right hand, respectively.

Figure 13. The four different targets used in Experiment 5.

Procedure Participants sat approximately 60 cm in front of the monitor and were instructed to respond to the pass direction of the basketball player as fast and as accurately as possible by pressing the left or right response button. One trial consisted of a fixation cross (500 ms), the basketball player in the initial position (1000 ms), the head turn to one side (social cue; presentation duration in dependence of SOA), and the target with the basketball player executing the pass (until response; see Figure 14).

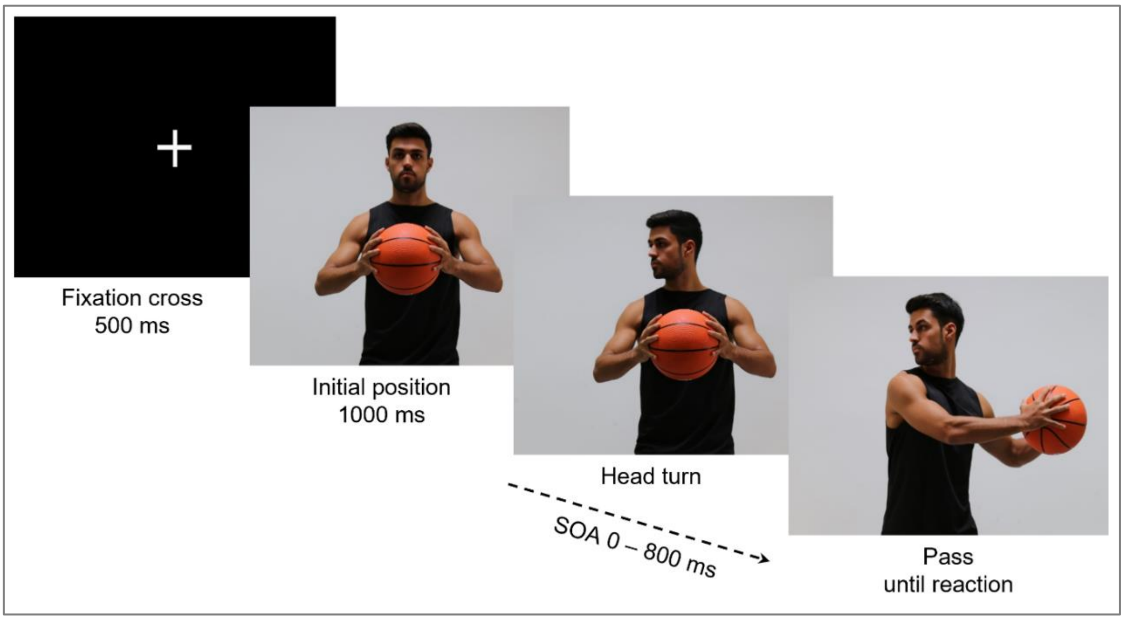

Figure 14. Sequence of a trial in Experiment 5.

The stimulus-onset asynchrony (SOA) between the head turn, and the pass was varied between 0 and 800 ms, in steps of 100 ms. In the SOA 0 condition, no preceding head turn was presented. In total, 36 conditions were used: head and pass congruent to the left, head and pass congruent to the right, head left with pass right (i.e., head fake left) and head right with pass left (i.e., head fake right) in combination with the nine different SOA. After a correct response was given, a blank screen was shown for 2000 ms before the next trial started. In case of an incorrect response, the word "Fehler" (German word for "error") was displayed on the monitor for 500 ms. In the beginning, participants carried out 36 practice trials (one trial for each condition), in order to get familiar with the task. Afterwards, 720 experimental trials were randomly presented (each condition 20 times) in four blocks of 180 trials each. Between each block, participants could take a rest.

Data Analyses Reaction times (RTs) below 100 ms and above 1500 ms (0.04 %) as well as wrong answers (1.03 %) were excluded from RT analysis. The mean errors (ERs) in percent were calculated from incorrect responses. Mean RTs were submitted to a repeated measures ANOVA with the factors *type of pass* (pass with or without head fake) and *SOA* (0 ms, 100 ms, 200 ms, 300 ms, 400 ms, 500 ms, 600 ms, 700 ms, and 800 ms). In case of a violation of the sphericity assumption, results were corrected according to Greenhouse-Geisser. For multiple comparisons, the alpha value was Bonferroni-Holm corrected and the corrected *p*-values are reported.

3.2.2 Results

Reaction Times Mean reaction times are illustrated in Figure 15A. Results showed a significant main effect for *type of pass* [$F(1, 22) = 39.58$, $p < .001$, $\eta_p^2 = .64$] as well as *SOA* [$F(2.58, 56.75) = 89.7$, $p < .001$, $\eta_p^2 = .8$]. These main effects were qualified by the interaction between both factors [$F(4.35, 95.59) = 8.11$, $p < .001$, $\eta_p^2 = .27$]. As can be seen from Table 1, the head-fake effect steadily increased from 2 ms at SOA 0 ($d = 0.08$) to 34 ms at SOA 300 ($d = 1.58$), and again decreased to 16 ms at SOA 800 ($d = 0.65$). Post-hoc *t*-tests were computed for the head-fake effect in dependence of SOA. Significant differences for pass and head congruent conditions as compared to incongruent conditions were found for each SOA between 100 and 800 ms ($ps \leq .046$).

No significant head-fake effect was found for SOA 0 (p = .695). The effect size for each SOA can be seen in Table 1.

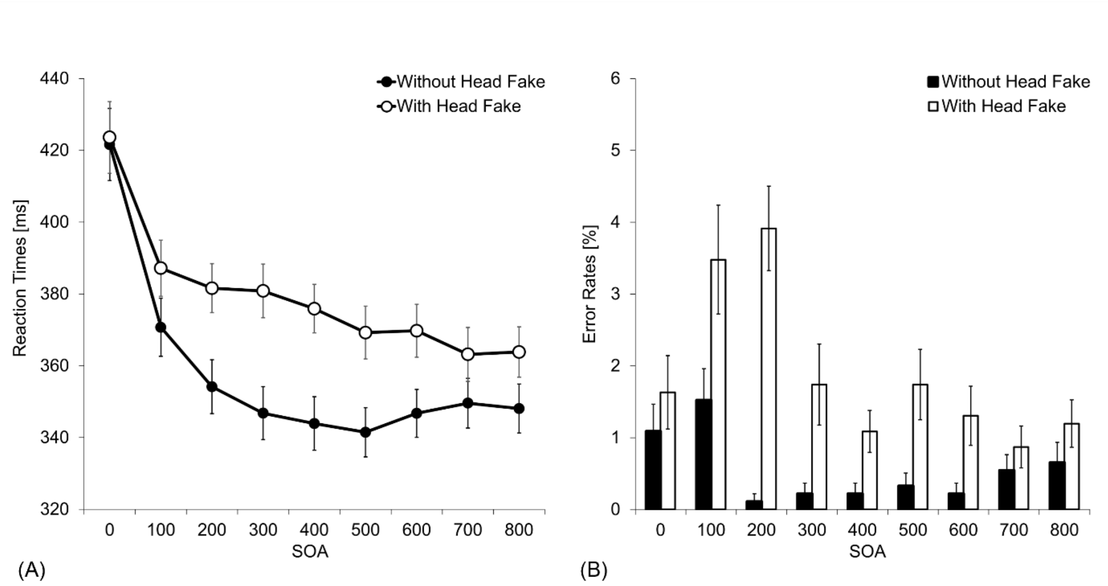

Figure 15. Results of Experiment 5. Mean reaction times ± SE (A) and mean error rates ± SE (B) for the pass without a head fake (blank circles/columns) and the pass with a head fake (black circles/columns) as a function of SOA.

Table 1. Mean reaction times and head-fake effect in milliseconds and effect size for each SOA.

	Pass without head fake [ms]	Pass with head fake [ms]	Head-fake effect [ms]	Effect size *d*
SOA 0	422	424	2.0	0.08
SOA 100	371	387	16.5	1.07
SOA 200	354	382	27.4	1.27
SOA 300	347	381	34.1	1.58
SOA 400	344	376	32.0	1.44
SOA 500	341	369	27.8	1.23
SOA 600	347	370	23.0	0.84
SOA 700	350	363	13.6	0.51
SOA 800	348	364	15.8	0.65

To test for significant differences of the head-fake effect between the SOAs, post-hoc paired *t*-tests for the peak (SOA 300) compared to the smallest significant head-fake effect on the left (SOA 100) and on the right (SOA 700) were conducted. The *t*-tests revealed significant differences between SOA 300 and SOA 100 [$t(22) = 3.81$, $p = .002$, $d = 0.79$], as well as for SOA 300 and SOA 700 [$t(22) = 3.84$, $p = .002$, $d = 0.8$].Interestingly, the modulation of the head-fake effect in dependence of SOA seems to be driven rather by an exponential decrease of the RTs for passes without a head fake and not by an increase of the RTs for passes with a head fake (see Figure 15A). It seems like the decreasing reaction times for passes with a head fake can be described by a linear model (i.e., linear function), but the decreasing reaction times for passes without a head fake by a quadratic model (i.e., quadratic function). To further examine, which model fits the data best, curve analyses were carried out for passes with a head fake and for passes without a head fake. Since SOA 0 was different from the other SOAs (see discussion), it was excluded from these analyses. As was expected, the results for passes without a head fake did not show a significant fit of the linear model ($p = .125$, $r^2 = .35$), but a significant fit of the quadratic model [$F(2, 5) = 18.1$, $p = .005$, $r^2 = .88$]. For passes with a head fake, results showed a significant fit for the linear model [$F(1, 6) = 132.96$, $p < .001$, $r^2 = .96$], and for the quadratic model [$F(2, 5) = 65.79$, $p < .001$, $r^2 = .96$]. However, this result for the quadratic model is based on a significant result for the linear term ($p = .019$). The quadratic term of the quadratic model was not significant ($p = .387$).

Error Rates Mean error rates are displayed in Figure 15B. Since a Shapiro-Wilk test showed no normal distribution of the error rates (all $ps \leq .001$), a Wilcoxon test was used to test for significant head-fakes effects for each SOA. Results showed a significant effect for SOA 200 ($z = 3.1$, $p = .001$, $r = .65$). Participants committed more errors, when a head fake was presented (2.5 %) compared to passes without a head fake (0.11 %). No significant head-fake effect was found for all other SOA ($ps \geq .059$).

3.3 Discussion Experiment 5

The present study investigated the optimal temporal lag between the head turn and pass initiation on the size of the head-fake effect in basketball. The aim was to provide empirical data on how to generate a large head-fake effect in the observer, in order to gain further insights into the temporal organization of deceptive actions in sports. To this end, three static images of a basketball player were subsequently presented: a basketball player in initial position (ball and head oriented towards the front), the same basketball player with the head turned to the left or right, and the same basketball player performing a pass to the left or right (with or without head fake). The SOA between the head turn and the passing action was varied. In this regard, the present study was different to previous studies, in which the head turn, and the passing action were presented (almost) simultaneously (Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011). As expected, a congruency effect was found, that is, faster reactions and fewer errors in pass and head congruent conditions than in incongruent conditions, signifying the well-documented head-fake effect in basketball (Kunde et al., 2011). In the reaction times, this effect was significant at all SOAs, besides SOA 0. The head-fake effect increased from SOA 0 to SOA 300 and decreased again to SOA 700. Surprisingly, this modulation of the head-fake effect seems to only be based on an overly facilitation of reactions to passes *without* a head fake and not on increased difficulties for reactions to passes with a head fake.

The results clearly show that the head turn influences reactions to a subsequent target picture. As mentioned earlier, there are different conceivable mechanisms on how the preceding head turn could affect the processing of the following passing action, namely, a shift of visual attention (i.e., cueing effect) to the side of the head turn and/or an activation of the corresponding response (i.e., priming effect). Here, we argue that the modulation of the head-fake effect seems to be induced by priming effects and possibly additional effects of attention shift. The preceding head turn activates a response corresponding to the head turn. This response activation leads to a fast response in case of a pass without a head fake. However, if the target contains a head fake, the activation of the response was incorrect and the activation of the other response must start from the beginning. Moreover, the preceding head turn could lead to an attention shift to the corresponding side. In case of a pass without a head fake, the pass direction can be processed immediately. In case of a head fake, the attention must be re-oriented to the other side before the pass direction can be processed. In this regard, Langdon and Smith

(2005) found priming effects as well as effects of attention shift with social cues (i.e., head and gaze cues). Based on Posner et al. (1978), the authors argued that priming effects emerge earlier and lead to benefits (i.e., faster reactions in congruent conditions), whereas attention shifts need more time and cause additional costs (i.e., slower reaction in incongruent conditions) (Langdon & Smith, 2005). The fitting of our data to a linear and a curve model suggest that the modulation by SOA was driven by the passes without a head fake as indicated by a significant fit of the curve model. For passes with a head fake, the analysis revealed a significant fit for the linear model. Therefore, the data seem to imply that priming effects are responsible for the modulation of the effects. This view is supported by a significant head-fake effect in the error rates at SOA 200. Since this study did not contain a neutral condition, we cannot exclude an additional influence of attention shifts. However, in a preliminary study on the head-fake effect with static images, we used eye-tracking to examine possible overt visual attention shifts during the observation of head fakes. The results of 18 participants did not show any overt attention shifts, neither to the side of the head orientation nor to the pass direction. Thus, visual attention shifts might either be covert or not occur (Alhaj Ahmad Alaboud et al., 2016).

This modulation of the head-fake effect by the head turn seems to take place between SOA 200 and 600. For SOA 100, 700, and 800, we argue, that the effect is comparable to previous studies, which used single static images (Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011). For example, Kunde et al. (2011) only used a single image of a basketball player, which either depicted a pass with or without a head fake. Based on a series of experiments, the authors assume that the head-fake effect emerges at a perceptual level. That is, responses to passes with a head fake are suggested to be slower and more error-prone than responses to passes without a head fake, as head orientation and pass direction interfere during stimulus encoding (Kunde et al., 2011). When a head-fake target appeared, participants were engaged in solving the perceptual conflict in a first step. Specifically, participants had to identify the relevant stimulus feature (i.e., pass direction) and transmit it to the stage of response selection (Kornblum, 1994). During this process, however, no further conflict occurs, as the once identified stimulus feature (e.g., pass to the right) is always compatible with the response (e.g., right button press). Thus, for the case that head-turn and passing movement occur simultaneously (i.e., only a target image is used), the perceptual conflict covers a potential motor conflict, which occurs if the head turn precedes the passing movement, as the present results suggest. That is, the effect triggered by the head turn had not already unfold at SOA 100, but already decayed for the two longest SOA, and the effect was due to the incongruence of head and pass direction in the target (Kunde et al., 2011). In fact, the results for SOA 100, SOA 700, and SOA 800 were of similar size as those of previous studies with single static images (Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011).

A question, which arises in this context, is, why this effect of perceptual conflict was not similarly present at SOA 0. The difference between SOA 0 and all other SOA was that no picture of the head turn alone was used at SOA 0. After the initial position of the basketball player, the target picture followed directly. Possibly, participants were not prepared to respond directly after the initial position to the target, because in 89 % of the trials, the initial position was followed by the head turn. This argumentation is supported by the general reaction times, which were much larger at SOA 0 compared to all other SOAs. Therefore, participants had more time to solve the conflict, which was induced by the incongruent head orientation in the target. Moreover, a non-hypothesized result was the reduction of reaction times with increasing SOAs in general. This effect might be explained with unspecific response preparation and may be similar to the variable foreperiod effect (Langner et al., 2018; Niemi & Näätänen, 1981). When the time interval between a warning signal and a target is uncertain (i.e., it differs from trial to trial), reaction times are shorter when the interval is long, as compared to short intervals (Niemi & Näätänen, 1981).

The aim of the study was to examine at which temporal lag between the head turn and the initiation of the passing action the greatest possible head-fake effect occurs. The head-fake effect was largest for an SOA of 300 ms, However, the reaction times for passes with and without a head fake both decrease with increasing SOA (unspecific response preparation effect). Therefore, the question arises, which strategy should be recommended for sports practice. When considering the whole RT pattern, a basketball player should turn his/her head simultaneously while initiating the passing action, otherwise the full benefit of the head fake is weakened by an effect of unspecific response preparation. Simultaneous movement execution should also be much easier to implement in practice than a temporal lag of 300 ms.

This study was limited to basketball novices. However, previous studies showed that the head-fake effect can be found with novices as well as basketball experts (Weigelt et al., 2017), which is assumed to be based on an automatic processing of the head orientation (Kunde et al., 2011). Future studies should investigate if this result can also be replicated with basketball experts. In addition to that, future studies could also focus on the deceiving athlete. Among others, interesting questions here are, if and how it is possible to train the optimal temporal organization of the head fake, and if there are any costs, which come along with performing a head fake.

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Repeating head fakes in basketball: Temporal aspects affect the congruency sequence effect

Chapter 4

Abstract The head fake in basketball is used to hinder the anticipation performance of an opponent. During a head fake, a player turns the head into one direction, but passes the ball to the opposite direction. Several studies showed that responses to the pass direction are slower when a basketball player applies a head fake, which is known as the head-fake effect. While this effect in general is very robust, some studies showed a modulation by the trial sequence, signified by a reduced or eliminated effect when two head fakes are performed in succession. The present study examined the question how this so-called congruency sequence effect (CSE) is influenced by different timings. To this end, the interval between the response to the previous target and the onset of the next target (response-stimulus interval, RSI; Exp. 6) and the interval between two targets (inter-stimulus interval, ISI; Exp. 7) were manipulated. Results revealed a CSE for the short ISI (500 ms), and even a reversed effect for the short RSI (500 ms). Interestingly, the intermediate (2000 ms) and long (5000 ms) ISIs and RSIs did not show a CSE, but also no head-fake effect. Results are discussed regarding practical demands and theoretical implications.

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Author contributions:

AP, IG, and MW conceived the study. AP was in charge of overall direction and planning of the experiments. AP analyzed the data. AP wrote the manuscript with helpful input from IG and MW.

4.1 Introduction

In many competitive sports, athletes use deceptive actions to hinder the anticipation performance of their opponents (for a review on deceptive actions, see Güldenpenning et al., 2017). For this purpose, the information given about an executed action can be reduced or delayed, or misleading information can be applied (Jackson et al., 2006). A well-studied example for the use of misleading information is the head fake in basketball. During a head fake, a basketball player turns the head into one direction, but passes the ball to the opposite side. Responses of an opponent to the pass direction are slower and more error-prone when passes with a head fake are performed as compared to passes without a head fake (Kunde et al., 2011; Polzien et al., 2021; Weigelt et al., 2017). This so-called *head-fake effect* has been found to be very robust, as it occurs, for example, with different experimental setups (Alhaj Ahmad Alaboud et al., 2016; Friehs et al., 2020; Polzien et al., 2020, 2021), with different instructions (Güldenpenning et al., 2019), and with cognitive load (Güldenpenning et al., 2020a). Moreover, the head-fake effect can be observed after extensive practice (Güldenpenning, Schütz et al., 2020), after visual and motor training, and also in basketball experts (Güldenpenning et al., 2020b; Weigelt et al., 2017). This robustness seems to be due to the automatic processing of the head orientation (Weigelt et al., 2020), which can hardly be suppressed (Güldenpenning et al., 2019; Kunde et al., 2011).

Most relevant for the present study is that the size of the head-fake effect may depend on whether a head fake is repeated, or not. Accordingly, a reduced (or even vanished) head-fake effect was observed, when the preceding trial contained a pass with a head fake, but a standard head-fake effect, when the current trial was preceded by a pass without a head fake (e.g., Güldenpenning et al., 2018; Güldenpenning et al., 2020a). This phenomenon is known as *Gratton effect* (Gratton et al., 1992) or *congruency sequence effect* (CSE; e.g., Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner, 2007). The CSE is of practical interest for the head fake in basketball, since the presence of a CSE means that the effectiveness of a head fake is reduced, when a basketball player has just encountered a head fake a moment before. Thus, the head fake loses its impact on the opponent when it is repeated. Moreover, the execution of a fake action might come along with costs for the faking player as well (Güldenpenning, Weigelt, & Kunde, 2020). In this regard, Güldenpenning, Weigelt, & Kunde (2020) observed larger reaction times for the execution of a pass with a head fake as compared to a pass without a head fake, when participants had no or little (800 ms) time for the preparation of the action.

The CSE for the head-fake effect in basketball was observed with novices (Güldenpenning et al., 2020a) and basketball experts (Weigelt et al., 2017), when using static (Friehs et al., 2020) and dynamic stimuli (Güldenpenning et al., 2018), and for simple (Alhaj Ahmad Alaboud et al., 2012) as well as complex responses (Alhaj Ahmad Alaboud et al., 2016). However, there are other studies on the head-fake effect in basketball, which did not find a CSE at all (Kunde et al., 2011), which only revealed a CSE in some experiments or groups (Alhaj Ahmad Alaboud et al., 2012; Weigelt et al., 2017), or which indicated only little differences between the head-fake effect after a preceding fake or non-fake action (Güldenpenning et al., 2020a; Güldenpenning, Schütz et al., 2020).

When looking at these previous studies examining the presence of a CSE on the head-fake effect in basketball in more detail, it appears that they used somewhat different experimental setups (e.g., static vs. dynamic stimulus material). This may be the reason for the inconsistent results with regard to the CSE. One factor that could explain these different patterns of results, which has not yet been systematically investigated for the head-fake effect in basketball, are the temporal aspects of successive trials. Usually, the target (i.e., task-relevant stimuli) in these experiments is presented until response is given. The interval between the response to the previous target and the onset of the next target (response-stimulus interval; RSI) varies between experiments. For example, in Experiment 1 by Kunde et al. (2011), static images were used and participants were instructed to respond by a left or right button press to the pass direction of a basketball player, who either performed a pass with or without a head fake. The standard head-fake effect was found, but at the same time, with a short RSI of 250 ms (i.e., a fixation cross was displayed for 250 ms after the response and before onset of the next target), no modulation of the effect in terms of a CSE was observed (Kunde et al., 2011). Weigelt et al. (2017) used the same experimental setup and replicated the previous results by Kunde et al. (2011) with non-athletes and soccer players. In contrast to these two groups, a CSE was found for basketball experts (Weigelt et al., 2017). However, in both experiments, error feedback was given, that is, when participants committed an error, the word “Fehler” (German word for “error”) was presented on the screen for 500 ms. Hence, in case of an error, the RSI changed to 750 ms. In most other experiments, the RSI was significantly longer. Alhaj Ahmad Alaboud et al. (2012), for example, also used static images in their Experiment 1, but manipulated the fake frequency (25 %, 50 %, 75 % head fakes). A CSE was observed with novice participants and an RSI of 2250 ms (i.e., between response to the previous target and onset of the next target, a blank screen was presented for 2000 ms and then a fixation cross appeared for 250 ms). In a number of other experiments, videos were used with complex response modes (e.g., Güldenpenning et al., 2018, 2020a; Güldenpenning, Schütz et al., 2020). Participants were asked to place their hands on start buttons at the beginning of a trial and then respond with a whole-body movement to the side the basketball player passed the ball. In these experiments, the RSI was often 1500 ms, plus the time participants needed to place their hands at the start buttons again (e.g., Güldenpenning et al., 2018, 2020a). Some of these studies found a CSE (e.g., Güldenpenning et al., 2018; Güldenpenning et al., 2020a), while others found (almost) no CSE (Güldenpenning, Schütz et al., 2020). From these different patterns of previous results, the question arises how much time should elapse between the performance of two head fakes (on the same opponent), so that the head fake does not lose its effectiveness. Hence, the aim of the present study was to extend the relevant knowledge on the CSE for the head-fake effect in basketball.

The CSE is a well-known phenomenon in different kinds of conflict tasks, like the Simon task (Simon, 1969; Simon & Rudell, 1967), the Stroop task (Stroop, 1935), and the Eriksen flanker task (Eriksen & Eriksen, 1974). In all these tasks, a task-irrelevant stimulus feature causes a conflict during the processing of a task-relevant stimulus feature. In the Stroop task, for example, participants are asked to read a color word (e.g., red), while ignoring the color in which the word is presented (e.g., blue; Stroop, 1935). The conflict becomes apparent in a congruency effect characterized by slower and more error-prone responses in conflicting trials as compared to trials without a conflict (Braem et al., 2019; Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014). In all these conflict tasks, a CSE can be found. Currently, it is under debate if the CSE is based on top-down attentional processes or on bottom-up mnemonic or associational mechanisms, or maybe on both (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner, 2014; Notebaert et al., 2006).

The *feature-integration* account, for example, assumes that stimulus and response features of the current trial are temporally bound together in a common episodic memory file (Hommel, 2004; Mayr et al., 2003). The activation of one feature causes a bottom-up co-activation of the other feature as well. Hence, fast reactions are to be expected when the current trial is a complete repetition of the previous trial or a complete alternation. However, when there is only a partial repetition of the previous trial, the co-activation of one feature, caused by the other, has to be overcome (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner, 2007). Several studies have addressed the question if the CSE could be exclusively based on bottom-up feature integration. However, the results are heterogeneous: While some studies did not find a CSE after controlling for feature and response repetitions (e.g., Mayr et al., 2003; Nieuwenhuis et al., 2006), other studies still observed a CSE, which is possibly based on top-down control (e.g., Egner et al., 2010; Schmidt & Weissman, 2014).

In this regard, the *conflict-adaptation* account is based on the conflict monitoring hypothesis (Botvinick et al., 2001) and views the CSE as an expression of cognitive control after monitoring a conflict. While attention is focused on the task-relevant feature of a stimulus after the occurrence of a conflict, the attentional control is loosened when no conflict occurs. Since the irrelevant feature is given less attention after incongruent trials, performance in subsequent incongruent trials is enhanced. As the irrelevant feature is helpful in congruent trials, the performance in subsequent congruent trials is worsen (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner et al., 2010).

Another account, which assumes top-down attentional influences is the account of *repetition expectancy* (Duthoo, Abrahamse, Braem, & Notebaert, 2014; Egner et al., 2010; Gratton et al., 1992). According to this view, the attentional focus is also strengthened or loosened in dependence of the preceding trial. However, this adaptation is executed, because of the expectancy that the congruency (congruent/incongruent) of the next stimulus will match the preceding one, and is therefore more proactive as compared to reactive conflict-adaptation processes (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner et al., 2010).

Egner et al. (2010) conducted a study on a face-word Stroop task and examined the relative contributions of the attention-based mechanisms, while controlling for bottom-up mnemonic influences. This was accomplished by two experiments, in which temporal aspects of the trial sequences were manipulated. In both experiments, the stimulus set consisted of female and male faces, which were labeled with the words “female” and “male”. The words could be congruent or incongruent to the images. Participants were instructed to indicate if the target depicted a female or male face by pressing a left or right button. In Experiment 1, the target was presented for a fixed duration of 1000 ms. The inter-stimulus interval (ISI), which is the time interval between the offset of the previous stimulus and the onset of the next stimulus, was varied in ten steps between 500 ms and 7000 ms. In Experiment 2, the target was presented until the response occurred and the RSI was manipulated between 500 ms and 5000 ms in ten steps. Egner et al. (2010) point out, that manipulating the ISI also influences the RSI and vice versa, which was why both experiments were conducted. For example, fast responses (e.g., in congruent trials) in the ISI experiment result in longer RSI as slow responses (e.g., in incongruent trials). Egner et al. (2010) hypothesized that the CSE caused by specific expectations would take some time to occur and then remain constant or increase over time, whereas the CSE based on reactive adaptation processes would occur rapidly and then decay, or would also persist over time. The results in Experiment 1 revealed a CSE, which was steadily decreasing with longer ISI, and which was absent for ISI 4000 to 5000 ms and longer. As in Experiment 1, a CSE was also observed in Experiment 2, and the effect decreased with increasing RSI. However, the effect was already absent for RSI 2500 to 3000 ms and longer. Egner et al. (2010) argued that their results are in line with a reactive conflict-adaptation account of the CSE, but not with an expectation-based account (for similar findings, see Duthoo, Abrahamse, Braem, & Notebaert, 2014).

Temporal aspects of the CSE are not only relevant to investigate the underlying processing mechanisms (cf. Duthoo, Abrahamse, Braem, & Notebaert, 2014; Egner et al., 2010; Notebaert, 2006), but are of special interest for practical demands for the head-fake effect in basketball. In the present study, we used a manipulation similar to Egner et al. (2010), but applied it in the context of the head fake in basketball. Participants were instructed to indicate the pass direction of a basketball player, who performed either a pass without or a pass with a head fake. In previous studies on the head-fake effect, different RSIs between trials were used (e.g., Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018; Kunde et al., 2011). However, these RSIs have not been systematically manipulated. In order to keep the design comparable to previous studies, but to systematically investigate the role of the length of the RSI, the temporal lag between response to the previous target and onset of the following target (RSI; 500 ms, 2000 ms, 5000 ms) was manipulated in Experiment 6. Since in this experiment the target presentation ends with a given response, the ISIs have the same length as the RSIs. For this reason, Experiment 7 was conducted to examine if the results in Experiment 6 are due to the ISI or RSI. This was accomplished by three different ISIs (500 ms, 2000 ms, 5000 ms). To obtain these three ISIs, the target in Experiment 7 had a fixed presentation duration of 1000 ms. However, reaction times in head-fake experiments with static images are usually much shorter than 1000 ms (e.g., Kunde et al., 2011; Weigelt et al., 2017). Therefore, the target should still be present after the reaction had occurred. Hence, the RSI in Experiment 7 consisted of the length of the ISI plus 1000 ms, minus reaction time. Moreover, the manipulation of RSI and ISI also influences the stimulus-onset asynchrony (SOA), which is defined as the interval between the onset of one stimulus and the onset of the next stimulus. In Experiment 6 (RSI), fast responses result in a short SOA, whereas slow responses result in a long SOA. In Experiment 7 (ISI), the SOA is a result of the target duration (1000 ms), plus the ISI (500 ms, 2000 ms, 5000 ms; for an overview of RSI, ISI and SOA, see Table 2).

Table 2. Relationship between RSI, ISI and SOA in Experiment 6 and 7.

	ISI	**RSI**	**SOA**
Experiment 6 (RSI)	500 ms 2000 ms 5000 ms	500 ms 2000 ms 5000 ms	Reaction time + RSI
Experiment 7 (ISI)	500 ms 2000 ms 5000 ms	1000 ms – RT + 500 ms 1000 ms – RT + 2000 ms 1000 ms – RT + 5000 ms	1000 + ISI

Note. RSI = response-stimulus interval; ISI = inter-stimulus interval; SOA = stimulus-onset asynchrony; RT = reaction time.

In the present experiments, the three different RSIs and ISIs were randomly presented within blocks. A long history of research on the foreperiod effect indicates that different intervals between a warning signal and a target influence the reaction time (e.g., Karlin, 1959; Langner et al., 2018; Sanders, 1975). In this context, responses are usually shorter for short intervals, when different intervals are presented across separate blocks (constant foreperiod effect). In contrast, variable intervals between a warning signal and a target within blocks result in longer reaction times for short intervals and shorter reaction times for long intervals (variable foreperiod effect). This phenomenon seems to be independent of the absolute length of the foreperiod (Langner et al., 2018; Niemi & Näätänen, 1981).

We expected the variable foreperiod effect to occur (i.e., decreasing reaction times with longer RSIs and ISIs) due to variable time intervals within blocks. Moreover, we hypothesized to find a standard head-fake effect in both experiments, independent of the length of the intervals. In Experiment 6, we expected a CSE to be found with the short and intermediate RSI, whereas no CSE should be observed with the long RSI (cf. Alhaj Ahmad Alaboud et al., 2012; Duthoo, Abrahamse, Braem, & Notebaert, 2014; Egner et al., 2010). Since the ISIs are accompanied by longer RSIs (depending on reaction times), we expected a CSE to be found with the short and possibly the intermediate ISI, but no CSE with the long ISI (Exp. 7).

4.2 Experiment 6

Experiment 6 examined how the CSE for the head-fake effect in basketball is influenced by temporal aspects. To this end, a design similar to that used in previous studies on the head-fake effect (e.g., Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011; Weigelt et al., 2017) was used, but the RSI was systematically manipulated.

4.2.1 Methods and Materials

Participants An *a priori* sample size analysis was calculated using MorePower 6 (Campbell & Thompson, 2012). To achieve a power of .95 (given $\eta_p^2 = .2$, $\alpha = .05$), 34 participants were required for detecting an interaction effect between all three factors.[8] Forty participants took part in the experiment. One participant carried out only one block and was therefore excluded from the sample. Moreover, boxplot analyses were carried out to screen the data for outliers. Participants, who were marked as extreme outliers in at least half of the conditions, were excluded from the data set. As a consequence, two additional participants were excluded due to extreme values in half of the conditions (both had on average more than 70 % errors in the conditions with the head fake). Extreme values were defined as values with a distance of more than 3*IQR (interquartile range) from the first and third quartile. Another participant was excluded due to high reaction times. After excluding 14.7 % of the trials due to premature responses (below 100 ms) or late responses (above 1500 ms), the boxplot still revealed extreme values of this participant in eleven of twelve conditions. Hence, the final sample consisted of 36 participants without any specific expertise in basketball (16 females, 6 left-handed, M_{age} = 21.6 years, *SD* = 2.0 years). Participants were naïve regarding the aim of the study. Course credits were offered for participation. All participants reported normal or corrected to normal vision and gave written informed consent to participate. The study complied with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

[8] This sample size analysis also applies for Experiment 2.

Apparatus and Stimuli Four front view images of a male basketball player were used as stimuli (see Figure 16). The basketball player performed a pass to the left or right with his head either turned into the same direction (pass without head fake) or into the opposite direction (pass with head fake). The stimuli were created out of two photos of a pass with or without a head fake, respectively. These images were mirrored along the vertical axis to obtain equal stimuli for passes to the left and right. The stimuli were displayed with a size of 23.5 x 19.1 cm (689 x 850 pixel) on a 24” monitor. The software “Presentation” (version 20.0, Neurobehavioral Systems) was used to present the images and to record reaction times and response errors. Two horizontally aligned keys (“A” and “Ä” of a German keyboard) were used as response buttons.

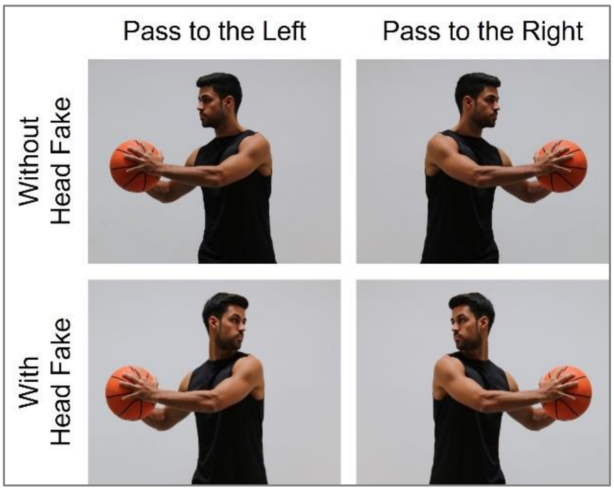

Figure 16. Stimuli for Experiment 6 and 7. The upper row depicts passes without a head fake. In the lower row, passes with head fakes are presented.

Procedure Participants sat approximately 60 cm in front of the monitor. They were instructed to respond to the pass direction of the basketball player by pressing the left button for a pass to the left and the right button for a pass to the right with their left or right index finger, respectively. Each trial consisted of a fixation cross and the target (pass to the left or right with or without a head fake). The target was presented until the response occurred (see Figure 17).

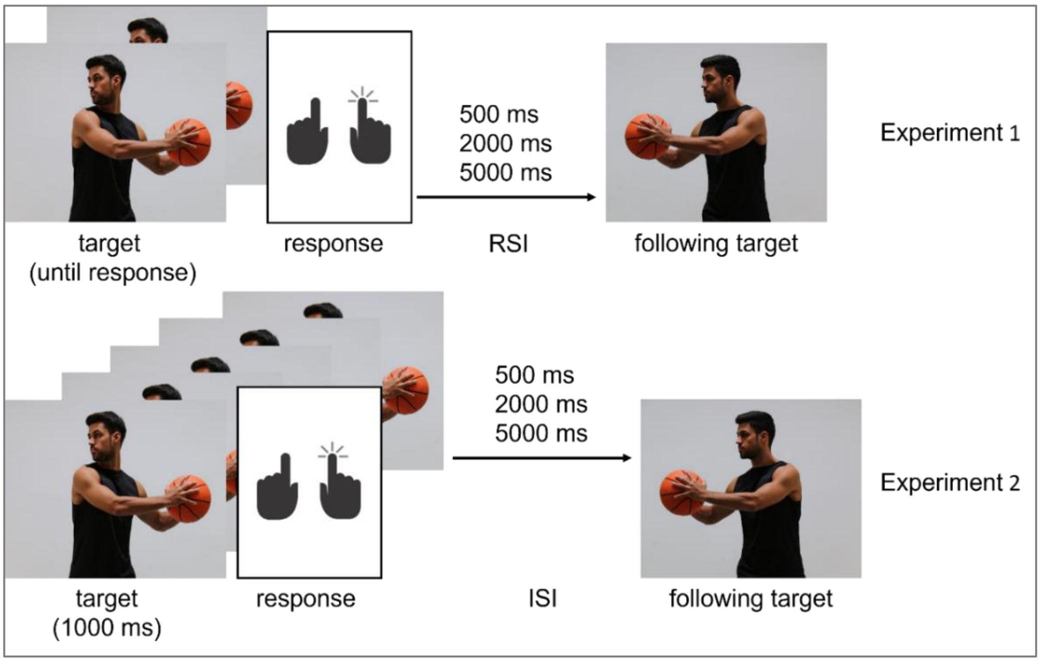

Figure 17. Designs of Experiment 6 and 7. The upper row depicts the design of Experiment 6. In the lower row, the design of Experiment 7 is shown.

The fixation cross was shown for the duration of the RSI (500 ms, 2000 ms, 5000 ms), which was defined as the interval between the response to the previous target and the onset of the next target. The different trials were presented randomly. The experiment started with a practice block (24 trials, i.e., each condition twice) to allow the participants to get familiar with the task. Afterwards, two experimental blocks with 180 trials each were carried out. Hence, each condition was presented 30 times. Participants could take a rest between the blocks.

Data Analyses In total, 3.0 % of the trials were treated as outliers. RTs below 100 ms and above 1500 ms (0.01 %), as well as wrong responses (3.0 %) were excluded from analyses. In addition to outliers, the first trial of both blocks was removed since this trial has no preceding trial, and thus, a CSE could not be calculated. The dependent variables reaction time (RT) and error rate (ER) were submitted to repeated measures analyses of variance (ANOVAs) with the within-subject factors *type of pass in trial n* (pass without head fake vs. pass with head fake), *type of pass in trial n-1* (pass without head fake vs. pass with head fake) and *RSI* (500 ms vs. 2000 ms vs. 5000 ms). If the sphericity assumption was violated, the degrees of freedom and the *p*-values were corrected according to Greenhouse-Geisser. For multiple comparisons, the α-value was adjusted according to Bonferroni-Holm and corrected *p*-values are reported.

4.2.2 Results

Reaction Times Mean reaction times are displayed in Figure 18 (lines). The repeated measures ANOVA showed a significant two-way interaction between type of pass in trial *n* and type of pass in trial *n*-1 [$F(1, 35) = 13.57$, $p < .001$, $\eta_p^2 = .28$]. Moreover, the interaction between all three factors was also significant [$F(2, 70) = 4.17$, $p = .019$, $\eta_p^2 = .11$]. No main effect and none of the other two-way interactions were significant (*p*s ≥ .120).

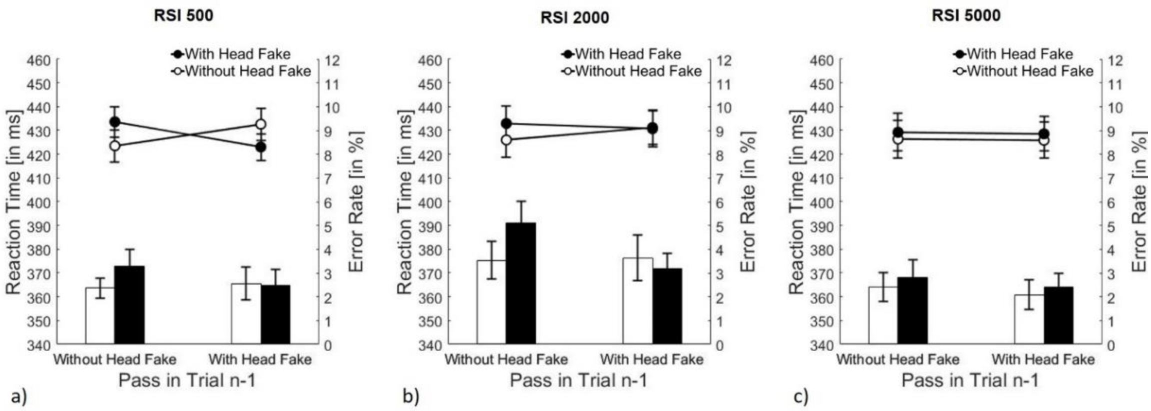

Figure 18. Results of Experiment 6. Mean reaction times (lines) ± *SE* and mean error rates (columns) ± *SE* for type of pass in the current trial (without head fake/with head fake) as a function of type of pass in the preceding trial (without head fake/with head fake) for a) RSI 500 ms, b) RSI 2000 ms, and c) RSI 5000 ms.

To follow up the three-way interaction, separate ANOVAs were conducted for each RSI. The ANOVA for RSI 500 showed neither a significant main effect for type of pass in trial *n*, nor for type of pass in trial *n*-1 (*p*s ≥ .734), but a significant interaction between both factors [$F(1, 35) = 12.40$, $p = .001$, $\eta_p^2 = .26$]. Post-hoc *t*-tests revealed a significant head-fake effect in the current trial when the preceding trial was a pass without a head fake [$t(35) = 2.58$, $p = .014$, $d = 0.43$]. When the preceding trial contained a head fake, the results for a pass with and without a head fake in the current trial also differed significantly [t(35) = 2.70, $p = .022$, $d = 0.45$]. However, this result was based on faster responses for passes with a head fake as compared to passes without a head fake. The ANOVA for RSI 2000 revealed no significant effects (*p*s $\geq .075$), neither did the ANOVA for RSI 5000 (*p*s $\geq .214$).

Error Rates The repeated measures ANOVA on mean ERs (see Figure 18, columns) revealed a significant main effect for RSI [$F(2, 70) = 5.49$, $p = .006$, $\eta_p^2 = .14$]. Post-hoc *t*-tests showed that reactions were more error-prone for RSI 2000 ($M = 3.9$ %, $SD = 3.9$ %) as compared to RSI 500 ($M = 2.7$ %, $SD = 2.8$ %) [$t(35) = 2.50$, $p = .034$, $d = 0.42$], and also as compared to RSI 5000 ($M = 2.4$ %, $SD = 2.7$ %) [$t(35) = 2.98$, $p = .015$, $d = 0.50$]. The difference between RSI 500 and RSI 5000 was not significant ($p = .565$). No other main effect nor any interaction reached significance (*p*s $\geq .059$).

4.2.3 Discussion Experiment 6

Experiment 6 examined the question how different time intervals between response to the previous target and onset of the next target affect the occurrence of the CSE in case of the head-fake effect in basketball. In contrast to our predictions, no variable foreperiod effect occurred as similar reaction times were observed for each RSI. Moreover, the results showed no main effect for pass in trial *n*, neither in general, nor for the separate RSIs. This is surprising, because the head-fake effect has been found to be very robust and has been replicated in several studies (e.g., Güldenpenning, Schütz et al., 2020; Polzien et al., 2021; Weigelt et al., 2017). However, the results for the short RSI (500 ms) showed a standard head-fake effect, when the preceding trial was a pass without a head fake, and a modulation of the head-fake effect, when the preceding trial was a pass with a head fake. This type of modulation was somehow unexpected and different from the results by Egner et al. (2010), because the head-fake effect was not only absent, but even reversed. This may also have led to the lack of a main effect for type of pass in trial *n* (i.e., standard head-fake effect), since the average reaction time for passes with and without a head fake was the same (both 428 ms). Interestingly, this inversed pattern after a head fake for the RSI 500 ms is in line with the assumption of early processes, namely bottom-up processes, which are based on feature integration (Hommel, 2004; Mayr et al., 2003). A pass with a head fake followed by a pass with a head fake is either a complete repetition (e.g., pass with a head fake to the right followed by a pass with a head fake to the right) or a complete alternation of the previous target (e.g., pass with a head fake to the right followed by a pass with a head fake to the left) and thus, either co-activates the correct features, or does not produce any co-activation at all. In contrast, a previous pass with a head fake followed by a pass without a head fake (e.g., pass with a head fake to the right followed by a pass without head fake to the left) results in a partial stimulus repetition and a co-activation of the wrong response (right). Hence, longer reaction times should be expected. However, our results suggest that the benefits of complete feature repetition and complete feature alternation are larger than the effect produced by the head fake itself.

Even though the two-way interaction for the RSI 2000 ms did not reach significance, the pattern of results seems to be similar to that obtained by Alhaj Ahmad Alaboud et al. (2012, Exp. 1). These authors also used static images to investigate the influence of the fake frequency on the head-fake effect in basketball. In their study, a significant CSE was found with an RSI of 2250 ms. The head-fake effect after trials without a head fake was 9 ms (present Experiment 6 = 7 ms) and the effect after a head fake was 1 ms (present Experiment 6 = 0 ms).

The fact that the two longer RSIs did neither evoke a CSE nor a standard head-fake effect points to additional strategic influences. In this regard, participants might have tried to actively suppress the head orientation and to focus on the pass direction. This would fit the assumption that top-down control needs more time to be executed (Notebaert et al., 2006). Interestingly, these results are not in line with the assumption of reactive conflict-adaptation processes, since enhanced attentional control would only be expected following a conflict (i.e., a pass with a head fake), but this control should be loosened after a pass without a head fake (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner et al., 2010). A similar pattern should be expected in case of repetition expectancy, since participants would exert attentional control after an incongruent trial, based on the assumption that the next trial would match the previous one. However, the control should be loosened after a congruent trial (Duthoo, Abrahamse, Braem, Boehler, & Notebaert., 2014; Gratton et al., 1992). In contrast, the adaptation processes with the intermediate and long interval in the present Experiment 6 were exerted independently of the preceding trial. These results are in line with proactive control, which is based on the global expectancy of upcoming head fakes.

Similar modulations of the head-fake effect have already been observed in the above-mentioned study by Alhaj Ahmad Alaboud et al. (2012), who examined the influence of fake frequencies on the head-fake effect. When using a single target, the authors found a head-fake effect when the fake frequency was low (i.e., 25 %) or intermediate (i.e., 50 %), whereas no head-fake effect could be observed when the fake frequency was high (i.e., 75 %; Alhaj Ahmad Alaboud et al., 2012, Experiment 1). Among others, the authors discuss attention shift as a possible explanation for their results. In this regard, participants could have actively tried to focus their attention on the relevant stimulus feature (Alhaj Ahmad Alaboud et al., 2012), signifying a strategic adaptation process.

The head-fake effect in the error rates was not significant, and hence, no modulation of the effect could be observed. However, the error rates were quite low, preventing any potential effects to show up. This pattern of results for the error rates with a low percentage of errors is in line with previous studies (e.g., Alhaj Ahmad Alaboud et al., 2012; Friehs et al., 2020; Weigelt et al., 2017).

4.3 Experiment 7

The aim of Experiment 6 was to examine how different temporal lags between the response to the previous target and the onset of the next target affect the CSE for the head-fake effect in basketball. The design was similar to that used in previous studies on the head-fake effect (e.g., Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011; Weigelt et al., 2017). However, this design does not allow to differentiate between the RSI and the ISI, since both have the same length (see Table 2). Therefore, in Experiment 7, the targets were presented for a fixed duration, and three different ISIs were used between the targets. Hence, the RSI in this experiment depended on reaction times.

4.3.1 Methods and Materials

Participants In total, forty participants took part voluntarily in this experiment. One participant was excluded from the data set, due to responses consistently with the wrong response button. As in Experiment 6, boxplot analyses were carried out to screen for outliers. As a result, one additional participant was excluded due to high error rates (more than 20 % errors in half of the conditions). Hence, the final sample consisted of 38 participants (17 females, 6 left-handed, M_{age} = 21.9 years, *SD* = 2.7 years). The participants had no special expertise in basketball and were naïve regarding the aim of the study. Course credits were offered for participation. All participants reported normal or corrected to normal vision and gave written informed consent to participate. The study complied with the standards of the sixth revision (Seoul) of the 1964 declaration of Helsinki. Moreover, this research was reviewed and approved by the Ethics Committee of the Paderborn University.

Apparatus, Stimuli, and Procedure The apparatus and stimuli of Experiment 7 were the same as in Experiment 6. The procedure only differed regarding the trial sequence. The fixation cross was displayed for the same time interval (500 ms, 2000 ms, 5000 ms) as before, but the target was presented for a fixed duration of 1000 ms. Therefore, in Experiment 7, the ISI was manipulated. As in Experiment 6, a practice block (24 trials) and two experimental blocks with 180 trials each were carried out. Participants could take a rest between the two experimental blocks.

Data Analyses In total, 2.1 % of all trials were treated as outliers. Reaction times below 100 ms and above 1500 ms (0.3 %) were removed from the data set. Moreover, wrong responses (1.8 %) were excluded from reaction time analysis. As in Experiment 6, mean RTs and ERs were submitted to repeated measures ANOVAS. The within-subject factors were *type of pass in trial n* (pass without head fake vs. pass with head fake), *type of pass in trial n-1* (pass without head fake vs. pass with head fake), and *ISI* (500 ms, 2000 ms, 5000 ms). In case of violation of the sphericity assumption, the degrees of freedoms and *p*-values were corrected according to Greenhouse-Geisser. For multiple comparisons, the α-value was adjusted according to Bonferroni-Holm and corrected *p*-values are reported.

4.3.2 Results

Reaction Times Mean RTs are displayed in Figure 19 (lines). The repeated measures ANOVA revealed a significant main effect for type of pass in trial *n* [$F(1, 37) = 7.21$, $p = .011$, $\eta_p^2 = .16$] and for ISI [$F(1.20, 44.47) = 8.17$, $p = .004$, $\eta_p^2 = .18$]. Participants reacted slower, when a pass with a head fake was presented (*M* = 432 ms, *SD* = 45 ms) as compared to a pass without a head fake (*M* = 429 ms, *SD* = 45 ms). The overall reaction times were slower for the short ISI (*M* = 439 ms, *SD* = 50 ms) as compared to the intermediate ISI (*M* = 427 ms, *SD* = 45 ms) [$t(37) = 3.67$, $p = .003$, $d = 0.60$] and the long ISI (*M* = 426 ms, *SD* = 44 ms) [$t(37) = 2.68$, $p = .022$, $d = 0.44$]. The difference between the intermediate and long ISI was not significant ($p = .853$). The main effect for pass in trial *n*-1 was not significant, neither was any two-way interaction ($ps \geq .099$). The two significant main effects were qualified by a significant interaction between all three factors [$F(2, 74) = 4.51$, $p = .014$, $\eta_p^2 = .11$].

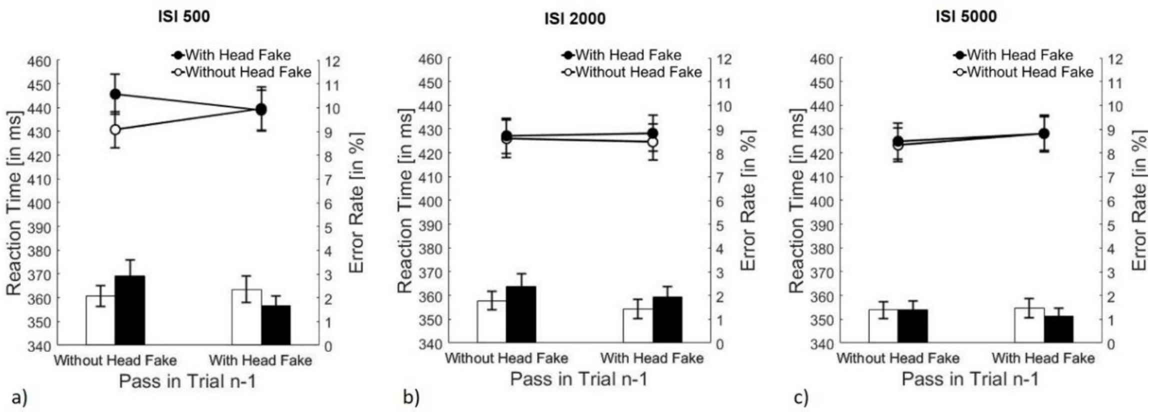

Figure 19. Results of Experiment 7. Mean reaction times (lines) ± *SE* and mean error rates (columns) ± *SE* for type of pass in the current trial (without head fake/with head fake) as a function of type of pass in the preceding trial (without head fake/with head fake) for a) ISI 500 ms, b) ISI 2000 ms, and c) ISI 5000 ms.

To follow up the interaction, three individual ANOVAs were conducted for each ISI. The ANOVA for ISI 500 showed a significant main effect for type of pass in trial *n* [$F(1, 37) = 7.06$, $p = .012$, $\eta_p^2 = .16$], but no significant main effect for type of pass in trial *n*-1 ($p = .678$). The significant main effect was qualified by an interaction of type of pass in trial *n* and type of pass in trial *n*-1 [$F(1, 37) = 8.46$, $p = .006$, $\eta_p^2 = .19$]. Post-hoc *t*-tests revealed a significant head-fake effect, when the preceding trial was a pass without a head fake (15 ms) [$t(37) = 4.43$, $p < .001$, $d = 0.72$], but no significant head-fake effect, when the preceding trial contained a head fake (-1 ms) [$t(37) = 0.16$, $p = .876$, $d = 0.03$]. The ANOVA for the ISI 2000 showed no significant effect ($ps \geq .297$), neither did the ANOVA for the ISI 5000 ($ps \geq .063$).

Error Rates The repeated measures ANOVA on mean ERs (see Figure 19, columns) showed a significant main effect for the factor ISI [$F(2, 74) = 5.08$, $p = .009$,

η_p^2 = .12]. Post-hoc *t*-tests revealed a significant difference between ISI 500 and 5000 [$t(37) = 3.01$, $p = .015$, $d = 0.49$]. Participants committed more errors when the ISI was 500 ms (M = 2.3 %, SD = 2.3 %) than when the ISI was 5000 ms (M = 1.3 %, SD = 1.6 %). The other single comparisons were not significant (ps ≥ .080). No other main effect and no interaction reached significance (ps ≥ .096).

4.3.3 Discussion Experiment 7

The aim of Experiment 7 was to examine the time course of the CSE for the head-fake effect in basketball by manipulating the inter-stimulus interval between two targets. As hypothesized, the different ISI led to a variable foreperiod effect, signified by slower reaction times for the ISI 500 ms as compared to the two longer ISIs and higher error rates for the short ISI as compared to the long ISI. Also, the results of the RTs showed a significant CSE for the short interval, which was characterized by a head-fake effect when the preceding trial contained no head fake, but no effect, when the preceding trial was a pass with a head fake. As already mentioned, the manipulation of the ISI had an impact on the RSI. In this regard, the fixed target duration of 1000 ms led to an RSI of on average more than 1000 ms, as participants mostly reacted faster than 500 ms after target onset and were then presented with the fixation cross for 500 ms (ISI 500), 2000 ms (ISI 2000), and 5000 ms (ISI 5000). Therefore, the RSI in this experiment was a result of the target duration (1000 ms), minus response time and plus the ISI (see Table 2). With an average reaction time of 439 ms, the short ISI of 500 ms comes along with an RSI of about 1000 ms. Hence, this RSI lies between the short and intermediate intervals in Experiment 6.

In contrast to the results by Egner et al. (2010), the perception of a fake action did not affect the response to the next target when the interval between two targets was intermediate. However, Egner et al. (2010) used different stimulus material and ten different ISIs and calculated the CSE averaged for two adjacent ISIs. Thus, the experimental setup might explain the marginal differences in results. In line with our predictions, no CSE was observed for the long interval. As in Experiment 6, the ISI 2000 ms and 5000 ms did not only show no CSE, but also no standard head-fake effect, pointing to additional strategic influences.

In the error rates, no head-fake effect could be observed, and hence there was also no modulation of the effect.

4.4 Discussion Experiment 6 and 7

Different studies on the head-fake in basketball showed a reduced or eliminated head-fake effect, when two fake actions are presented in rapid succession (e.g., Alhaj Ahmad Alaboud et al., 2012; Friehs et al., 2020; Güldenpenning et al., 2020a). This effect is known from other psychological conflict tasks and is called *congruency sequence effect* (CSE; Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner, 2007). For real sports scenarios, it seems to be relevant how fast head fakes may be applied in succession without losing its benefit. This seems especially important since the execution of a fake action might come along with costs for the faking player as well (Güldenpenning, Weigelt, & Kunde, 2020). The present study aimed to answer the question if and how the CSE is influenced by temporal aspects of two successive trials. To this end, two experiments were conducted, in which static images of a basketball player were used, who performed a pass with or without a head fake. Participants were instructed to respond to the pass direction by pressing a left or right key. In Experiment 6, the temporal lag between the response to the previous target and the onset of the next target was manipulated (RSI; 500 ms, 2000 ms, 5000 ms). The manipulation of the RSI was in line with previous studies on the head-fake effect, in which the target was presented until response (e.g., Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011; Weigelt et al., 2017). In Experiment 7, the target appeared for a fixed duration of 1000 ms and the ISI (500 ms, 2000 ms, 5000 ms) between the offset of the previous target and the onset of the next target varied.

In accordance with previous research on the variable foreperiod effect (e.g., Langner et al., 2018; Niemi & Näätänen, 1981), we expected reaction times to become shorter with longer intervals. The extensive literature on the head-fake effect (e.g., Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011; Polzien et al., 2021) led to the assumption that a head-fake effect would occur in all conditions. Based on previous studies on the CSE in face-word Stroop tasks (Egner et al., 2010) and the head-fake effect (Alhaj Ahmad Alaboud et al., 2012), we also hypothesized to find a CSE with the short and intermediate RSI, but no CSE with the long RSI. Moreover, we expected to observe a CSE with the short ISI, a reduced or vanished CSE with the intermediate ISI, and no CSE for the long ISI (Duthoo, Abrahamse, Braem, & Notebaert, 2014; Egner et al., 2010).

In contrast to our hypotheses, the results of Experiment 6 did not show the typical pattern of the variable foreperiod effect, which is signified by slower reactions for short intervals as compared to long intervals. Furthermore, the standard head-fake effect was not found in general, but only a modulation of the head-fake effect for the short RSI. This modulation was characterized by a standard head-fake effect, when the preceding trial was a pass without a head fake and a reversed effect (i.e., shorter reaction times for passes with a head fake), when the preceding trial was a pass with a head fake. This inversed pattern is in accordance with the assumption of bottom-up processes, which are based on feature integration (Hommel, 2004; Mayr et al., 2003). In this regard, a perceived event (e.g., a stimulus) generates an event file, which contains the stimulus information, the task context, and the action produced. If the next event includes at least one of the features that is bound in the event file, the event file is activated again. This event file produces partial repetition costs if the activated codes only match the current event partially. Hence, responses should be fast, if a current event is either a complete repetition or a complete alternation of the previous event (Hommel, 2004). In the short RSI condition of Experiment 6, this was the case, when a pass without a head fake was preceded by a pass without a head fake (424 ms) or a pass with a head fake was preceded by a pass with a head fake (423 ms). However, only some features were repeated, when a pass with a head fake was preceded by a pass without a head fake (434 ms) or a pass without a head fake was preceded by a pass with a head fake (433 ms).

In line with our predictions, the variable foreperiod effect was observed in Experiment 7. Moreover, the results in Experiment 7 revealed a typical CSE for the short ISI, which was characterized by a standard head-fake effect following a pass without a head fake, but an eliminated effect, when the preceding trial was a pass with a head fake. A difference between the short RSI and the short ISI was that the interval between the response to the previous target and the onset of the next target was longer in Experiment 7 than in Experiment 6. This was due to the fixed target duration (1000 ms) in

Experiment 7, while participants' responses were much faster than 1000 ms. Hence, in Experiment 7, the target was still present after the response occurred, and the RSI consisted of this time plus the respective ISI (see Table 2).

An unexpected result of our study was the non-existent head-fake effect for the intermediate and long ISIs and RSIs. To our knowledge, previous studies on the head-fake effect, did neither use such long intervals as the present study, nor did they use variable intervals. Therefore, the question arises if long intervals produce similar patterns of results when they are presented blockwise, although, a standard head-fake effect would be expected if the previous trial does not influence the current trial anymore. Therefore, these results seem to be pointing to strategic processes (e.g., shift of attention to the relevant feature), which need time to be executed. Similar patterns of results have already been observed by Alhaj Ahmad Alaboud et al. (2012), who did not find a head-fake effect, when the fake frequency was high. When using a single target, the head-fake effect was gone with a fake frequency of 75 % (Experiment 1). For apparent motion, the head-fake effect could no longer be observed, when passes with and without a head fake were presented with 50 % or 75 % frequency (Experiment 2; Alhaj Ahmad Alaboud et al., 2012).

Moreover, a difference between the present task and the face-word Stroop task used by Egner et al. (2010) and Duthoo, Abrahamse, Braem, and Notebaert (2014) is that relevant and irrelevant stimulus features do not spatially overlap. Hence, the task in this study allows attention to be directed towards the relevant stimulus feature and ignoring the irrelevant stimulus feature, whereas the word in the face-word Stroop task is presented in the center of the face (in red color), and therefore cannot be ignored.

Importantly, the major aim of this study was to gain further insights into the time-course of the CSE for the head-fake effect in basketball to allow practical implications. In this regard, our results indicate that the use of two head fakes in very rapid succession eliminates the benefit (Experiment 7) or even leads to a disadvantage (Experiment 6) for the faking player. This became obvious by the result of the short ISI, in which a standard CSE was found, and the results of the short RSI, in which reaction times to passes with a head fake were even faster than to passes without a head fake, when they were preceded by a fake action. However, in real sports scenarios, it seems unlikely that the same player applies two head fakes within 500 ms. With regard to longer intervals, most importantly, the present results suggest that strategic processes also eliminate the benefits of a head fake, as indicated by no difference between the conditions for the intermediate and long ISIs and RSIs. Notably, in the present study, participants were always somehow expecting a head fake. In contrast, a real basketball game is not that predictable, because many different actions happen in rapid succession and suddenly a head fake is applied. Hence, a head fake in real sports scenarios might be somewhat more surprising than under laboratory conditions and the question arises if athletes can maintain top-down control over longer periods of time during these real-game situations.

In sum, this study showed modulations of the head-fake effect with all the ISIs and RSIs used. However, the processing of the stimuli with the longer intervals is most likely influenced by strategic processes. As mentioned earlier, it seems especially interesting for practical demands how top-down control is used to hinder the processing of the head orientation. Hence, future studies should examine the CSE for the head-fake effect in basketball with even longer intervals, in order to determine how long the strategic influences last. Moreover, it could be investigated how "noise" in terms of additional visual stimuli and responses between two passing actions, affects the size of the CSE. This approach might represent the real-sports scenario more closely.

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General Discussion

Chapter 5

In the last decade, numerous studies on the head fake in basketball have been conducted, which were able to demonstrate its effectiveness (e.g., Güldenpenning et al., 2018; Kunde et al., 2011; Weigelt et al., 2017). The present thesis had two overarching aims: first, to shed light on the underlying mechanisms of the head-fake effect with dynamic stimuli, and second, to identify factors influencing the effectiveness of head fakes in basketball. Seven experiments were conducted to answer various specific questions, which will be briefly summarized below. In addition, the individual results will be brought together and considered in particular with regard to the assumptions of the Theory of Event Coding (TEC; Hommel et al., 2001). Moreover, practical implications will be discussed.

5.1 Perceptual-Cognitive Mechanisms of the Head-Fake Effect

Previous studies on the head-fake effect in basketball identified the automatic processing of the head orientation as the cause of the head-fake effect for static images (Kunde et al., 2011; Weigelt et al., 2020), whereas other possible sources, such as bodily cues (Kunde et al., 2011) or the gaze direction (Weigelt et al., 2020), were excluded. It remained an open question, however, whether the head-fake effect is also solely based on a perceptual conflict when using dynamic stimuli or whether other causes (such as a conflict during response selection) play a role as well. The present thesis addressed this question of the underlying perceptual-cognitive mechanisms of the head-fake effect for dynamic stimuli (i.e., video presentations). In this regard, head fakes could have an impact on early perceptual processes (i.e., attention shift or interference during input selection) as well as on later processes (e.g., interference during response selection; Kunde et al., 2011). To answer this question, the Experiments 1 to 5 from this thesis examined the perceptual-cognitive mechanisms of the head-fake effect with dynamic stimuli.

In the present Experiment 1 to 4 (Chapter 2), videos of a basketball athlete executing a pass either without or with a head fake were used. Experiment 1 was based on the model of dimensional overlap (Kornblum, 1994), which suggests two possible causes for the head-fake effect (cf. Kunde et al., 2011): a dimensional overlap between the irrelevant stimulus feature (i.e., head orientation) and the relevant stimulus feature (i.e., pass directions; S-S interference) or a dimensional overlap between the irrelevant stimulus feature and the response (S-R interference). To test both possible mechanisms, the spatial overlap between irrelevant stimulus feature (i.e., head orientation) and response was resolved by arranging the response keys vertically instead of horizontally. The reaction time results showed an equally large head-fake effect for vertical as for horizontal key arrangement, arguing against a conflict at the level of response selection and in favor of a perceptual conflict. However, the results of the response errors were not that clear: The head-fake effect was seen in both conditions, but the effect was significantly smaller in the vertical condition than in the horizontal condition. This modulation of the effect in the response errors could potentially be due to an additional cause of the head-fake effect.

Experiments 2 to 4 (Chapter 2) were conducted to further investigate the underlying mechanisms of the head-fake effect. To this end, the AFM (Sternberg, 1969) was applied. Following the AFM, Experiments 2 and 3 tested whether the head-fake effect interacted with image quality, which would suggest a perceptual origin. While the lowering of image quality in Experiment 2 was not sufficient, the greater change in image quality in Experiment 3 led to an interaction. However, the effect had an opposite direction as compared to the one found by Kunde et al. (2011): With static images, the authors found an increased head-fake effect with reduced image quality (Kunde et al., 2011), whereas the results presented here, showed that the effect decreased along with the reduced image quality. The interaction by itself suggests a perceptual origin of the head-fake effect, however, the differences with Kunde et al. (2011) also suggest that perceptual-cognitive mechanisms differ for static and dynamic stimuli.

According to AFM, it is possible for two factors that interact with each other (i.e., influence the same process) to independently influence other stages (Sternberg, 1969, 2011). To test whether the head fake additionally triggers a conflict during response selection, Experiment 4 (Chapter 2) was conducted and the head fake stimuli were combined with a Simon task (Simon, 1969). The Simon task is considered to be a classical conflict task involving response selection (e.g., Hommel, 2019). Instead of responding to the direction of the pass, the task in this experiment was to respond to the color of the ball. In contrast to the predictions, the stimulus-response congruency between color of the ball and response side had no effect on its own, even though the color was relevant for the task. However, the irrelevant type of pass (no head fake vs. head fake) interacted with S-R congruency. According to the AFM (Sternberg, 1969) this can be interpreted as a strong indication for a conflict on the level of response selection during the observation of a head fake. An interesting finding of this experiment was that the congruency between the irrelevant head orientation and the response side was especially relevant for the reaction times: Reactions were slower when the head orientation and the response side were incongruent and faster when they were congruent. Thus, the results can be characterized as an interference effect between irrelevant stimulus feature (i.e., head orientation) and response. The automatic processing of the head orientation, although irrelevant for the task, might point to the social importance of the head orientation (c.f. Langton & Bruce, 1999; Langton et al., 2000). Furthermore, an important result was that responses were slower, when a pass with a head fake was combined with a congruent S-R mapping as compared to a pass without a head fake combined to an incongruent S-R mapping. In both conditions, the head orientation did not match the response side, but the head fake led to additional costs. This result points to an additional perceptual interference effect based on the head fake and is in line with the results of Experiments 1 to 3.

Further evidence for a cause of the head-fake effect during later (non-perceptual) processes were provided by Experiment 5 (Chapter 3), in which participants were again ask to respond to the pass direction of a basketball player. In Experiment 5 a trial consisted of three static images of a basketball player (an initial position, the head turn, and the pass). The head turn was presented at different time intervals before the passing action of the basketball player (SOA of 0 to 800ms). It is important to note that the conflicting information in the experiments by Kunde et al. (2011) and in the present Experiments 1 to 4 was presented simultaneously, whereas the irrelevant information (i.e., head orientation) in Experiment 5 preceded the passing action. The preceding head turn renders Experiment 5 similar to classical spatial cueing experiments (Posner, 1980), in which a spatial cue signals the location of a following target with a certain probability. For uninformative cues, the responses to targets at cued locations are usually faster than to targets at un-cued locations (Posner et al., 1978). It is often assumed that spatial cueing effects are based on an exogenous shift of attention to the cued location (e.g., Eimer, 1997; Ristic et al., 2002). However, some authors suggested a combination of attention shift and response activation as a cause for spatial cueing effects (e.g., Langdon & Smith, 2005; Paavilainen et al., 2016). The pattern of results for the different SOA between head turn and pass in Experiment 5 revealed in particular a facilitation in congruent conditions, which is assumed to be based on a response activation by the head orientation.

In sum, the results of the Experiments 1 to 5 from this thesis, together with the results by Kunde et al. (2011) and Schütz et al. (2020), suggest that there is not a single cause of the head-fake effect, but that the effect depends on the nature of the stimuli. Kunde et al. (2011) found convincing evidence that the head-fake effect produced by a single static image is based on some kind of perceptual mechanism when the head orientation indicates a different direction than the pass. However, videos (as in Experiments 1 to 4) as well as multiple static images (as in Experiment 5 and in Schütz et al., 2020) seem to also induce interference during response selection or might even lead to response activation.

Here, it is argued that both static and dynamic stimuli involve a perceptual interference, which is caused by the incongruent head orientation during a head fake and leads to slowed responses. Since no new information arrives with static images, the conflict is resolved and a response is initiated without further conflict occurring. In contrast, a continuous flow of new information takes place with dynamic stimuli, whereby the head orientation is processed even later and leads to feature code activation (see Section 5.2). This activation causes a conflict during later processes of information processing (e.g., during response selection) and leads to even more prolonged reaction times in case of a head fake. However, this activation by the head orientation also takes place in congruent conditions, in which a response facilitation can be observed for preceding head turns (Experiment 5, Chapter 3).

With regard to the perceptual origin of the head-fake effect, which they found for static images, Kunde et al. (2011) pointed out that it could be based on two different mechanisms: first, an attention shift, or second, some kind of input selection problem. In the case of an attention shift, the attention of the observer is drawn to the irrelevant head orientation. If a pass without a head fake is presented, the attention is already focused on the right side and the pass direction can be directly processed. In contrast, if a head fake is presented, the attention must be re-oriented to the other side, resulting in costs. In the case of an input selection problem, the conflicting directional information of head orientation and pass direction makes it harder to identify and process the relevant stimulus feature (i.e., the pass direction).

First evidence for differences between dynamic and static stimuli with regard to (overt) attentional shifts during a head fake was provided by Alhaj Ahmad Alaboud

(2018). In two experiments with static images and videos, respectively, the author used eye tracking to examine the gaze behavior of the participants. When participants were presented with single static images, they fixated the fixation cross and remained fixated until the response. In contrast, head fakes led to overt attentional shifts to the side of the head turn when using dynamic stimuli (Alhaj Ahmad Alaboud, 2018). An explanation for the underlying mechanism of exogenous attentional shifts offers the transient hypothesis, which assumes that the appearance of objects is accompanied by sensory transients, which capture attention (cf. Fuller et al., 2009). Different studies showed that changes in the environment, like the sudden change of luminance (Franconeri et al., 2005) and the onset of motion (Abrams & Christ, 2003), can capture attention. Hence, this hypothesis might explain, why Alhaj Ahmad Alaboud (2018) found overt attentional shifts with dynamic, but not with static images. Moreover, the exclusion of attentional shifts as the underlying perceptual mechanism for the head-fake effect with single static images, might point to interference during input selection (cf. Kunde et al., 2011).

The different processes, which can be influenced by a head fake are displayed in the upper part of Figure 20 using a stage model. In the lower part of Figure 20, it is shown which explanatory mechanisms in connection with TEC can be regarded as causal for the effect. Because TEC does not cover early perceptual processes (Hommel et al., 2001), the mechanisms hypothesized by TEC might only explain later perceptual processes (e.g., feature weighting as attentional process) and the processes of response selection and motor activation. To what extent the research results on the head-fake effect in basketball can be explained with TEC will be discussed in the next section.

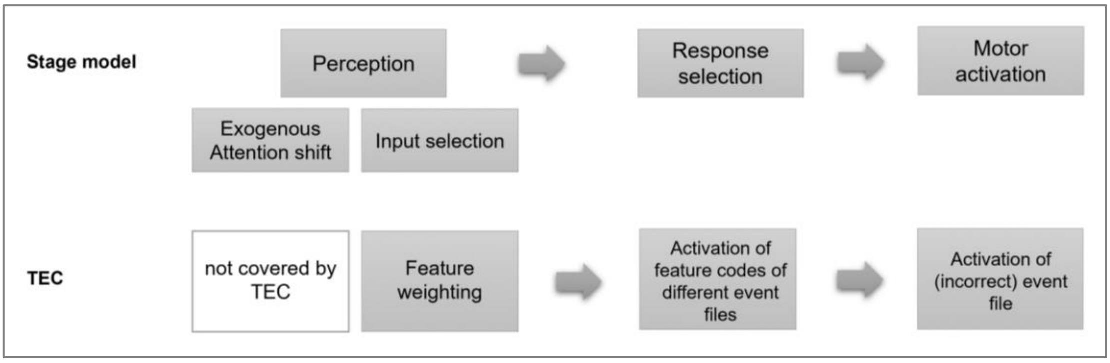

Figure 20. Possible perceptual-cognitive origins of the head-fake effect in basketball as can be assumed within stage models and explanations for the underlying mechanisms offered by TEC.

5.2 Explaining the Underlying Mechanisms with TEC

In this section, the mechanisms underlying the head-fake effect in basketball will be explained against the background of TEC. As pointed out in the previous section, the mechanisms underlying the head-fake effect in basketball differ depending on the type of stimuli used. Therefore, the different types of stimuli are considered separately in the next sections. Afterwards, factors that influence the strength of activation of event files are highlighted. Finally, this chapter clarifies to what extent the results and considerations within this thesis can be applied to other deceptive actions.

5.2.1 The Head-Fake Effect with Single Static Images

One reason Kunde et al. (2011) used single static images was to allow comparability with other psychological interference tasks, in which a task-irrelevant stimulus feature leads to interference during information processing (Kunde et al., 2011). While the results on the head fake with single static images point to a perceptual mechanism underlying the effect (Kunde et al., 2011), the results on the Simon task clearly suggest a conflict during response selection (for a review, see Lu & Proctor, 1995). The crucial difference between both tasks consists in the dimensional overlap of features and the resulting consequences with regard to the intentional weighting of feature dimensions. The feature weighting principle, proposed within TEC, is considered to prepare the system for upcoming events. With regard to perception, this preparation can be regarded as an attentional process, which allows the preferential processing of relevant features or feature dimensions (Hommel et al., 2001). Importantly, Memelink and Hommel (2013) emphasized:

> *"The intentional-weighting mechanism seems to work in such a way that weights are assigned to whole dimensions/domains such as color or location, rather than to specific feature values such as 'red' or 'up'. Activation (or putting more weight on a domain) results in a greater impact of feature values coded on this domain or dimension in subsequent cognitive operations."*
> (Memelink & Hommel, 2013, S. 257)

In case of the Simon task, the weighting mechanism results in a stronger weighting of the dimension color. Since there is only a feature overlap between stimulus and response (S-R), but no stimulus-stimulus (S-S) overlap between relevant feature (i.e., color) and irrelevant feature (i.e., stimulus location), the weighting mechanism can help the perceptual system to focus on the relevant feature by increasing the weight on the color dimension. However, since there is also a dimensional S-R overlap, the stimulus location cannot be completely ignored.

In case of a typical head-fake experiment, the pass direction and the response key are relevant for the task, so that both features are weighted heavily (cf. Weigelt & Güldenpenning, 2022). However, there is not only a dimensional S-R overlap between pass direction and response, but also an S-S overlap between pass direction and head orientation. The relevant feature (i.e., pass direction) leads to an increased weighting of the horizontal dimension (left vs. right). This affects not only the attention to the pass direction, but also to the head orientation, since it is also coded in terms of spatial feature codes. Here, it is argued that the observation of the two directional stimulus features lead to interference during input selection, based on the dimensional overlap between both features.

5.2.2 The Head-Fake Effect with Multiple Static Images

Using single static images means that the relevant stimulus feature (i.e., pass direction) and the irrelevant stimulus feature (i.e., head orientation) are always presented simultaneously. In contrast, in the apparent motion in Experiment 5 (Chapter 3), the head turn was presented before the relevant stimulus feature. A preceding head turn allows the feature codes of the event file for the response side corresponding to the head orientation to be activated early. When a pass (e.g., left) is preceded by a corresponding head orientation (e.g., left), the event file for the correct response is already pre-activated, so that the pass direction can easily activate the correct response (e.g., left). Therefore, the pre-activation of an event file by a preceding head turn leads in particular to a facilitation of responses to passes without a head fake, which was shown in Experiment 5. However, when a pass (e.g., left) is preceded by an incongruent head orientation (e.g., right), the incorrect event file is pre-activated by the preceding head turn, the activation of the correct event file by the relevant feature can only start with the presentation of the target picture. As a result of the early activation of the incorrect event file and the later activation of the correct event file, a response conflict between both event files emerges. Furthermore, TEC suggests that a sufficient activation of an incorrect event file might even lead to the activation of the associated motor pattern. This assumption is supported by the findings of Schütz et al. (2020), in which subliminal presented primes of a basketball player turning head and body to the side, were able to induce a whole-body response.

5.2.3 The Head-Fake Effect with Videos

In Experiment 1 to 4 (Chapter 2) of the present thesis and in other studies (e.g., Güldenpenning et al., 2020; Güldenpenning et al., 2019), videos were used, in which the directional features by the head and the pass were presented at the same time. However, in contrast to the observation of static images, the movement in the videos unfolded only over time. Alhaj Ahmad Alaboud (2018) showed that static and dynamic stimuli of the head fake in basketball differ with regard to overt attention shifts: During the observation of static images, participants focused their attention on the fixation cross and remained fixated at that location until response. In contrast, participants shifted their attention to the direction of the head orientation during the observation of dynamic stimuli (Alhaj Ahmad Alaboud, 2018). Here, it is argued that the attention shift leads to the direct processing of the head orientation and the activation of the corresponding feature codes when observing videos. When the attention is directed back to the relevant feature (i.e., pass direction), the corresponding feature codes are also activated. When a pass (e.g., left) with a corresponding head orientation (e.g., left) is presented, the spatial features uniformly activate the correct response (e.g., left). However, when a pass (e.g., left) is presented with a non-corresponding head orientation (e.g., right), the head orientation activates feature codes of the event file for the incorrect response, whereas the pass direction activates feature codes for the event file of the correct response. As a result, a response conflict or even a reaction to the wrong direction emerges (cf. Weigelt & Güldenpenning, 2022).

5.2.4 Factors Influencing the Strength of the Activation of Event Files

The results of this thesis suggest that the different manipulations used in the experiments lead to different (strong) activations of the event files. A first factor, which is of importance for the strength of the activation, is the time interval between the irrelevant and the relevant stimulus feature, as shown by the results of Experiment 5 (Chapter 3). The significant fit of the results for passes without a head fake to a curved model suggests that presenting the head turn before the pass causes the corresponding event file to be activated. The modulation of the head-fake effect as a function of SOA seems to reflect the time course in the activation of the event files, possibly in conjunction with a shift of attention. If no deception is subsequently shown, then the response is correspondingly fast. In this regard, a time interval of 300 ms between the head turn and the pass may cause the strongest activation of the event file and therefore, lead to the largest head-fake effect.

A second factor, which seems to influence the strength of the activation of an event file, seems to be image quality. In Experiment 3 (Chapter 2), the reduced image quality resulted in a less salient head turn and thus, attracted attention less quickly (see Section 5.1.1). Consequently, the reduced image quality could have led to a later and weaker activation of the associated event file, which in turn reduced the benefit of the correct activation, when subsequently a pass without a head fake was presented, and therefore, also reduced the head-fake effect.

Experiment 1 of the present thesis (Chapter 2) points to a third factor, which might influence the strength of activation of an event file, at least when using dynamic stimuli. As already pointed out previously, typical experiments on the head-fake effect contain a dimensional S-R overlap as well as an S-S overlap. While in the horizontal condition of Experiment 1, the head orientation, the pass, and the response key are coded on the same dimension (i.e., horizontal), in the vertical condition, only the head orientation and the pass direction are coded on the same dimension (i.e., horizontal), whereas the response key is coded on another dimension (i.e., vertical). Therefore, in the horizontal condition, the spatial code of the head orientation (e.g., left) activates the feature code for the pass direction (e.g., left) and for the response key (e.g., left), whereas in the vertical condition, a horizontal spatial code of the head orientation (e.g., left) only activates the feature code for the left pass direction (e.g., left), but not the feature code for the response key. As a result, the activation of the event file based on the head orientation in the vertical condition is lower as compared to the horizontal condition. The consequence is that the event file associated with the incorrect response is less often sufficiently activated to produce response errors, when observing head fakes. This was shown by Experiment 1, in which a significantly reduced head-fake effect in the response errors was found with vertical as compared to horizontal key arrangement.

5.2.5 TEC and other Types of (Deceptive) Actions

While so far TEC has only been considered in the context of the head fake in basketball, the anticipation of other (deceptive) actions will now be discussed. Within the taxonomy of deceptive actions in sports (see Section 1.1), deceptive actions can be distinguished into those based on the presentation of misleading information and those based on the reduction of action-relevant information (Jackson et al., 2006; Weigelt & Güldenpenning, 2022). The former aims at misleading the opponent into a wrong reaction, the latter tries to make it difficult for the opponent to anticipate the action and thus, delay his/her reaction (Weigelt & Güldenpenning, 2022). The head fake in basketball is an example for the presentation of misleading information (i.e., the incorrect direction indicated by the head orientation) by modification of a partial movement. As explained earlier, it is assumed that under certain conditions (e.g., preceding head turn), the event file of the incorrect response is activated and, when sufficiently activated, leads to the execution of the associated motor pattern (see Section 5.2.2).

Similar mechanisms can be assumed for deceptive actions in different sports, in which a player deceives his/her opponent about the direction s/he is running (e.g., Bishop et al., 2013; Brault et al., 2012; Mori & Shimada, 2013). An example of this is the side-step in rugby during which an attacking player attempts to run past the opponent and uses a side-step to misinform the opponent about the direction s/he is running (e.g., Brault et al., 2012; Mori & Shimada, 2013). In contrast to the head-fake, the deceptive direction signal can only be given *before* the honest signal. According to TEC and consistent with the head fake in basketball, it can be assumed that the incorrect direction signal by the side-step activates the feature codes of the incorrect response side. If sufficiently activated it might also trigger the associated motor pattern, which leads to a reaction of the defending player into the wrong direction. An increased number of incorrect responses after a side-step in rugby was, for example, observed by Brault et al. (2012), who asked expert and novice participants to judge the final running direction (i.e., left vs. right) of an attacking player in a virtual environment. This fake effect could be shown both when participants were asked to give their responses via a gamepad (Experiment 1) and when they were asked to perform an intercepting (whole-body) movement in the direction of the anticipated running direction of the attacking player (Experiment 2). What is interesting here is that different bodily cues (such as center of mass displacement and lower trunk yaw) can point to the intended running direction. However, other cues (such as head yaw, upper trunk yaw) are deceptive and suggest the other possible running direction. In this regard, experts and novices differ in terms of the cues they use, with novices being more likely to rely on deceptive signals (Brault et al., 2012). This is in line with previous research on anticipation performance in sports, which showed that experts rely on different and earlier postural cues as compared to novices (e.g., Abernethy, 1990; Müller et al., 2006).

Within TEC, the focus on different cues by experts and novices during the anticipation of honest and deceptive actions can be explained by the weighting mechanism (cf. Hommel et al., 2001; Memelink & Hommel, 2013). Expertise might not only lead to the integration of new feature codes, but also to an adjusted weighting of the feature codes, which are already integrated in the event file. As already pointed out before, feature weighting might tune the cognitive system to attend to relevant stimulus features (Hommel et al., 2001). In line with this, findings on gaze behavior of expert and novices revealed that experts fixate more on task-relevant cues as compared to novices (for a review see Gegenfurtner et al., 2011). While this knowledge of the relevant movement features enables experts to recognize an opponent's intention earlier (Brault et al., 2012; Güldenpenning et al., 2013), they initiate their response later as compared to novices (Brault et al., 2012; Savelsbergh et al., 2002), possibly to avoid incorrect reactions. Therefore, expertise could lead to a higher required threshold for the activation of an event file or the requirement of the activation of certain very significant feature codes, to trigger the associated motor pattern.

The head fake in basketball as well as the side-step in rugby use direction signals to misguide the opponent into the wrong direction. Other kinds of deceptive actions also aim at response activation, but are based on the initiation, termination, and (re-)initiation of a movement (cf. Weigelt & Güldenpenning, 2022). One example can be seen in team handball, where penalty throws can be faked (Cañal-Bruland, et al., 2010). The initiation of a first movement might activate the event file for the corresponding response and lead to a premature defense, so that the attacking player can take advantage of it. While this kind of deceptive action also involves the incorrect event file to be activated, other kinds of deceptive actions make it difficult for the opponent to identify the intended action by either complete omission of the initial movement or an indeterminant initial movement (c.f. Weigelt & Güldenpenning, 2022). One example can be observed in volleyball, in which action-relevant information is reduced by an indeterminate initial movement, which makes it hard to distinguish whether the player intends to play a lob or a smash (Güldenpenning et al., 2013). An example for the complete omission of the initial movement can be seen in team handball, when a hip shot is executed (almost) without backward movement of the arm (Weigelt & Güldenpenning, 2022). For both kinds of deceptive actions, TEC suggests that the missing or ambiguous information at the beginning of a movement leads to a late activation of the correct event file, which prevents the corresponding motor response from being triggered and thereby leads to a late reaction of the defender. In this context, it is also to be expected that experts show better anticipation performances as compared to novices, since they can better rely on early and subtle cues (e.g., Abernethy, 1990; Müller et al., 2006), which should be reflected in the event files, in which relevant cues should be amplified by the weighting mechanism.

5.3 Practical Implications

While in the last sections the question of the underlying mechanisms of the head-fake effect was addressed and considered against the background of TEC, in this section the question of practical implications will be discussed.

Experiments 5 to 7 explicitly addressed two applied aspects of the head-fake effect in basketball, in order to derive some practical implications. The aim of a basketball player, who performs a deceptive action is to gain an advantage over his/her opponent, which should be as large as possible. For this reason, Experiment 5 was conducted to examine if a temporal lag between the head turn, and the passing action generates a head-fake effect in the observer, which is larger as compared to a simultaneous presentation of the conflicting information. Results of this experiment revealed a modulation of the head-fake effect in dependence of the stimulus-onset asynchrony between head turn and pass. While the SOAs of 100 ms, 700 ms, and 800 ms showed head-fake effects of similar size like those observed in single target experiments (cf. Alhaj Ahmad Alaboud et al., 2012; Kunde et al., 2011), the largest effect was found with the SOA of 300 ms. Considering the overall results of the present thesis, an important benefit of the preceding head turn might be the (stronger) activation of the corresponding event file. This response activation takes time, but can actually trigger an interception movement to the wrong side (Schütz et al., 2020). Therefore, basketball athletes should turn the head slightly before the pass in order to increase their advantage over the opponent.

Moreover, Experiment 6 and 7 addressed the question if two head fakes can be performed in rapid succession, without losing its benefit. To this end, single static images were used and the response-stimulus intervals (500 ms, 2000 ms, 5000 ms; Experiment 6) and inter-stimulus intervals (500 ms, 2000 ms, 5000 ms; Experiment 7) were manipulated. Results revealed a modulation of the head-fake effect with all RSIs and ISIs used. Results for the short intervals indicated that performing two head-fakes in rapid succession eliminates the benefit (Experiment 7) or even leads to a disadvantage (Experiment 6) for the deceiving player. This inversed pattern of results can be explained by bottom-up processes based on feature integration (Hommel, 2004; Mayr et al., 2003). The assumption is that responses to trials, which are a complete repetition or a complete alternation of the previous trials are fast, whereas partial repetitions lead to costs. The longer intervals did not show a congruency-sequence effect, but also no standard head-fake effect. The latter effect points to the influence of top-down processes and longer lasting strategic cognitive control applied by the participants.

Similar adaptation processes have already been observed in other studies, which examined the influence of global (i.e., fake frequency) and local (i.e., fake repetition) context factors on the size of the head-fake effect (e.g., Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018). For example, Güldenpenning et al. (2018) found a CSE based on the local context information, but also a modulation of the size of the head-fake effect in dependence of the global context information. In this regard, a reduced head-fake effect could be observed, when a high amount of head fakes was presented. Interestingly, both effects were independently of each other. The authors argued that the CSE might be based on bottom-up processes, whereas participants might strategically adapt to the global context information of the fake frequency using top-down control (Güldenpenning et al., 2018). One explanation for such adaptation processes with high amounts of fake actions is a more focused processing of the relevant stimulus feature (Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018). While in the present Experiments 6 and 7, the intervals of 2000 ms and 5000 ms might have been too long for bottom-up feature integration to have had an impact, the interval might have been long enough to prepare for the upcoming event using top-down cognitive control.

With regard to practical implications, bottom-up processes, such as that of feature integration, can probably be neglected. A disadvantageous effect for the attacking (i.e., passing) player should only arise if two deceptive actions are played in very quick succession (i.e., 500 ms), which is rather unlikely. In contrast, top-down control can eliminate the benefit of a head fake. How long this control can be maintained within a real game scenario needs to be answered in future studies.

5.4 Conclusion

The present thesis had two main aims: first, to uncover the perceptual-cognitive mechanisms underlying the head-fake effect in basketball with dynamic stimuli, and second, to explore factors that have practical implications. To this end, this thesis built on two important approaches to the relationship between perception and action, namely sensorimotor and ideomotor theories. Sensorimotor approaches, such as stage theories of information processing, provide an overview of the information processing stages and allow testing of specific assumptions, for example, by means of the AFM (Sternberg, 1969). Even though, different authors assume different numbers of stages and various assumptions fundamental to AFM have been questioned, the AFM was often considered as a useful tool for making inferences about stages of information processing (e.g., Miller, 1988; Sanders, 1990). To the best of my knowledge, the present thesis was the first to apply the AFM using dynamic stimuli. The consistent results point to underlying mechanisms based on perceptual processes as well as later processes, depending on the type of stimuli. These results from Experiment 1 to 4 (Chapter 2) based on the AFM were further supported by Experiment 5 (Chapter 3), in which the temporal distance between head turn and pass was manipulated, using an apparent motion.

While stage models and the AFM (Sternberg, 1969) are able to identify the general processes on which a factor operates, the theory of event coding (Hommel et al., 2001) as an ideomotor theory, is able to explain, how these processes are influenced in more detail. In this regard, the results of the present experiments are in line with the assumptions derived from TEC (Hommel et al., 2001). Essentially, the head turn in Experiments 1 to 5 seems to activate the event file for the corresponding response (cf. Weigelt & Güldenpenning, 2022; see Section 1.3.5.2). In case of a pass without a head fake, the uniform activation of the event file for the correct response by the directional signals (i.e., head turn and pass) leads to fast reactions. In case of a head fake, the head turn activates feature codes of the event file for the incorrect response, while the pass direction activates the feature codes of the event file for the correct response. Hence, both event files compete with each other, which results in a slower reaction based on the response conflict or even a reaction to the wrong side. Interestingly, three factors could be identified that affect the strength of activation of event files: a) the temporal distance between the irrelevant (i.e., head turn) and the relevant (i.e., passing action) stimulus feature (Experiment 5), b) the saliency of the irrelevant stimulus feature (Experiment 3), and c) the number of features that dimensionally overlap (Experiment 1).

The assumption that a preceding head turn activates the event file for the corresponding response is also relevant from a practical perspective, since the activation of the event file depends on the temporal lag between head turn and pass. In this regard, a head turn that precedes the passing action by 300 ms produces the largest head-fake effect in the observer. Moreover, the activation allows to induce a reaction into the wrong direction in the observer, as already shown by (Schütz et al., 2020). Finally, Experiments 6 and 7 suggest that observers are able to suppress the processing of the head orientation based on strategic control processes. These findings should be considered when basketball players use the head fake during the game.

5.5 Outlook

The present thesis has highlighted the underlying mechanisms of the head-fake effect in basketball with dynamic stimuli, which involve perceptual and later processes. For both, multiple static images (i.e., apparent motion) and videos, results suggest that the head orientation activates feature codes of the event file for the corresponding response, which leads to interference during response selection or even execution of the incorrect response. While Alhaj Ahmad Alaboud (2018) showed that the head turn in videos also leads to an attention shift to the corresponding side, the question, if the preceding head turn also triggers an attention shift when using multiple static images, still has to be answered. Moreover, future studies could focus on the question, how large the contribution of which mechanism (i.e., attention shift and response activation) in the total effect is. Moreover, the question arises, whether the results found for the head-fake effect also hold for other deceptive actions. Assuming the mechanisms postulated by TEC (Hommel et al., 2001), different deceptive actions which are based on misleading information (e.g., side-step in rugby: Brault et al., 2012; fake shot in team handball: Cañal-Bruland et al., 2010; shot fakes in Basketball: Meyer et al., 2022) should involve similar perceptual-cognitive mechanisms, which should be examined in future studies.

From an applied perspective one main result of this thesis is that a preceding head turn activates the corresponding response. This result found with multiple static images should be corroborated by a manipulation of the SOA between head turn and pass when using videos.

Another interesting aspect for future research concerns the cognitive control processes after perceiving a head fake. Even though the processing of the head fake can hardly be suppressed, both previous studies (e.g., Alhaj Ahmad Alaboud et al., 2012; Güldenpenning et al., 2018) and the present thesis point to cognitive control processes after encountering a deceptive action. Different mechanisms have been proposed for these adaptation processes (cf. Alhaj Ahmad Alaboud et al., 2012), however, evidence for one or the other explanation is still missing. Furthermore, future studies should address the question of interindividual differences in cognitive control and how long-lasting cognitive control processes are in experimental designs, which reflect more closely real game scenarios. In this context, it also seems worth to more often incorporate new technologies, such as virtual environments.

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