Belief in streaks—known as a hot (or cold) hand in sports—is a common element in human decision making. In three video-based experiments, we investigated the belief–behavior relationship and how allocation decisions in volleyball are affected by the expertise of participants measured in years of experience. The participants watched video sequences of two volleyball players in which the base rates of these players were kept constant. In addition, one player showed a hot hand (or cold hand), which was manipulated by length and perfection. Results showed that participants of different expertise levels were sensitive to all kinds of streaks, allocated more/less balls to the hot/cold player and reported strong beliefs in the hot or the cold hand. Developing tactics can benefit from this line of research.

It is a widespread opinion that people’s behavior is influenced by streaks. These streaks, or sequential binary events, occur in myriad alternating orders over time and in many domains, such as: births, weather, stock market, players’ performances, game outcomes, and roulette (Oskarsson, Van Boven, McClelland, & Hastie, 2009). The crux of the matter is to say when an event is random and when not. Randomness and probabilities are an integral part of life and play a role in a number of phenomena and fallacies. For example the gambler’s fallacy in roulette, where the probability of the red color coming up is thought to decrease if red has come up several times in a row already. This phenomenon is called a fallacy, as the probability of red or black coming up always stays the same because of the independent identical distribution.

In the domain of sports, an opposite effect to the gambler’s fallacy is often described as the hot hand. The hot hand belief is the notion that a player has “a better chance of making a shot after having just made his last two or three shots than he does after having just missed his last two or three shots” (Gilovich, Vallone, & Tversky, 1985, p. 297). According to Gilovich et al., such over-interpretation of successful hits in a row (the law of small numbers) is a fallacy or misperception of random sequences. That a player is “hot” or is having “a run” means that the sequence of successful hits is perceived as systematic, and it is often explained as having a psychological momentum (e.g., Perreault & Vallerand, 1998).
hand and the psychological momentum are not identical but akin, as the momentum does not deal with inevitable streaks but does with “turning points” (Richardson, Adler, & Hankes, 1988, p. 69).

In line with this, Miller and Weinberg (1991) related their studies not specifically to the “hot hand” but more generally to the psychological momentum, which was described as tying the score after a deficit of three points. The tying team was predicted to win the match significantly more often than the other team. However, Taylor and Demick (1994) stated that “if perceived momentum is more than a cognitive illusion, then there must be some intervening factors that influence the transmission of the perception of momentum to a change in performance” (p. 4), thus indicating the importance of search for such factors in applied sport psychology.

Our goal in this article is to investigate the belief–behavior relationship in sports concerning positive and negative performances, to understand the behaviors of coaches, players, and spectators in situations of streak. For instance, a playmaker’s belief about whether a recently successful player will continue his streak (hot hand) or is likely to stop it (gambler’s fallacy) could alter his allocation strategy. These strategies are often categorized as momentum or contrarian strategies for predicting uncertain events, such as the success of a player or the development of the stock market (Tyszka, Zielonka, Dacey, & Sawicki, 2008). If people believe that a player’s streak will continue, they tend to use momentum strategies, otherwise they prefer contrarian strategies. These strategies have not been examined in the context of the hot hand belief in sports yet.

The belief in the hot hand is widespread, and the phenomenon has been analyzed in many different domains, such as sports (in 13 sport disciplines—archery: Filho, Moraes, & Tenenbaum, 2008; baseball: Frohlich, 1994; basketball: Adams, 1992; billiards: Adams, 1995; bowling: Dorsey-Palmateer & Smith, 2004; darts: Gilden & Wilson, 1995; golf: Clark, 2003, 2005; handball: Dumangane, Rosati, & Volossovitch, 2009; hockey: Morrison & Smittlein, 1998; horseshoe pitching: Smith, 2003; soccer: Jones & Harwood, 2008; tennis: Klaassen & Magnus, 2001; volleyball: Gula & Köppen, 2009), sport science (Hales, 1999), psychology (Tyszka et al., 2008), and economics (McFall, Knoeber, & Thurman, 2009). There is no empirical data showing a negative hot hand, the so-called cold hand in sports. Studies showing effects of cold hands could extend research on the hot hand by looking into behaviors in situations in which the focus is on unlucky streaks, such as when a player should be replaced.

Bar-Eli, Avugos, and Raab (2006) summarized the last two decades of hot hand research in sports by declaring that there is disagreement in the field of hot hand research, with two nearly commensurate camps for and against the hot hand. These two camps claim that the hot hand belief is either a fallacy (Gilovich et al., 1985) or not (Larkey, Smith, & Kadane, 1989). Furthermore, studies focusing on hot hand behavior have found that the hot hand belief can be used as an adaptive strategy under specific conditions. That is, when there is a positive correlation of the actual and the average performance of a player (Burns, 2004; Gula & Raab, 2004). Calling the hot hand a fallacy is based on the opinion that the belief is caused by: (1) a memory bias due to long sequences of hits (or misses) that are more memorable than alternating sequences, and (2) a misperception of chance based on the law of small numbers, that is, that short sequences of random events are often overestimated. The different opinions might be grounded on different perspectives of situational and personal factors.
Hot hand research focuses on different situational (e.g., sport discipline, manipulation of hot hand sequences) and personal (e.g., gender, age, expertise) factors. A recent important factor studied is the length of the sequence. For instance, the “rule of three” says that the third repeat event in a sequence is pivotal to the event being perceived as a streak because of the importance of the number “3” in human learning, cognition, and religious belief. There are three dimensions, three basic colors, and the Holy Trinity (Carlson & Shu, 2007). Similarly in sports, testing different lengths of streaks and their structure provided further evidence that the hot hand belief is manifested after short sequence successes (Larkey et al., 1989). This implies it is reasonable to call and to perceive a player as “hot” after three successful attacks in a row, whereas nothing is known for the opposite, the cold hand belief.

Personal factors are often focused on in studies regarding different disciplines, such as differences in problem representation and procedural knowledge between elite and non-elite springboard divers (Huber, 1997), expertise-based differences of athletes in psychology (Raab & Johnson, 2007), expertise and age differences of pilots during decision making (Morrow et al., 2009), and gender differences in physics (Taasoobshirazi & Carr, 2008). Expertise in sports is an important classification system of athletes that is measured by the level of performance and the number of years of experience. Only little attention has been paid to it in the field of hot hand research. However, one exception was found and analyzed in a recent study by Gula and Köppen (2009), where both situational and personal factors of hot hand beliefs and behaviors were tested. They used different kinds of hot hand sequences in allocation decisions (distribution of the ball to attack players) of novices and experts in volleyball. These hot hand sequences were manipulated by the parameters perfection and length (four conditions: perfect, short: three hits in a row; perfect, long: four hits in a row; imperfect, short: four attacks with one miss; imperfect, long: five attacks with one miss). Results showed that participants were strongly influenced by streaks—novices even more than experts. A significant interaction of expertise and the perfect/long condition indicated that experts, in this study, did not allocate as many balls to the hot hand player as the novices did, as the experts were less influenced by long hot hand sequences.

The study was limited for a number of reasons. First, expertise was defined as having experience in playing volleyball. However, whether different levels of expertise or position-specific expertise play a crucial role could not be tested. Second, Gula and Köppen’s study was the first of its kind, and therefore, it requires replication to justify practical applications that differentiate situational and personal factors.

To summarize, after 20 years of hot hand research the analyses, descriptions, and explanations of this phenomenon are not satisfying. As indicated above, the situational and personal factors as well as their interaction have not been tested well enough yet, and the cold hand phenomenon has not been investigated at all so far. These points have inspired further research to fill the remaining gaps in the current state of knowledge.

**Goals of the Studies and Hypotheses**

The central goal was to investigate whether belief in the hot or cold hand differs regarding the participants’ expertise in their preferred sport—this expertise was defined by the performance level and by the duration of experience measured by years. For being an expert the participants had to practice in a club at regional level
for at least ten years. We developed three studies that were conducted in volleyball for two reasons: (1) The design of the studies for replication purposes followed the design of the Gula and Köppen (2009) study; (2) volleyball is a structured environment in which the allocation to a player cannot be directly hindered, and due to the separation of the field volleyball can appropriately demonstrate the hot hand belief–behavior relationship; in other sports (e.g., basketball) the allocation decision can be influenced by more factors, such as intensive defense of the opponents.

In Study 1 we analyzed experts and beginners in sports other than volleyball. As Gula and Köppen (2009) showed that sport-specific expertise influences the decision-making process, the aim of Study 1 was to test the limits of these expertise effects by comparing general sport experience to sport-specific experience for hot hand sequences. We expected that general sport experience would have an influence on the allocation decisions in volleyball, but that this effect might be smaller than that of sport-specific experience. Assuming that experts would pay more attention to the equal average performances (base rates) of two volleyball players, we expected experts to be less strongly influenced by the hot hand information than beginners would be. Therefore, experts would allocate fewer balls to the hot hand player.

In Study 2 we concentrated on individual and team athletes without experience in volleyball. The previously analyzed factor “general experience” was subdivided into these two groups, making it possible to define whether a specific type of experience (individual vs. team sport) was more or less influenced by hot and cold hand sequences. In addition, we analyzed the potential differences in individual and team athletes concerning the hot hand. We hypothesized that individual athletes would be influenced by the hot hand of a player more than team athletes, as individual sports are more likely to show nonrandom sequential dependencies in performance, than team sports are, because of the external factors (teammates, opponents, defense, tactical instructions of the coach) that affect performance (Oskarsson et al., 2009). In addition, we assumed that the reciprocal relationship between self-efficacy and positive performance (Bandura, 1997) would be perceived to be higher by individual athletes than team athletes. Therefore, we predicted that individual athletes would allocate more balls to the hot player.

In Study 3 we put the focus on individual and team athletes without experience in volleyball again. This time we analyzed the influence of cold hand sequences on allocation decisions in volleyball. We wanted to identify whether cold hand sequences lead to fewer (following the logic of the hot hand) or more (following the logic of the gambler’s fallacy) allocations to the cold player compared with the previous studies. This study was exploratory because of the lack of cold hand studies in sports. We predicted that cold hand sequences would influence the allocation decisions in the same way as hot hand sequences, meaning that positive performance would lead to increased allocations to the hot player and negative performance would lead to decreased allocations to the cold player. Furthermore, the individual athletes would be more strongly influenced because they would be more likely to take individual negative performance into account as “choking under pressure”, which is known as highly trained athletes failing to perform in high-pressure situations (e.g., Jordet, 2009).

The differentiation of experts across the three studies (general sports experience in Study 1 and sport-type-specific experience in Studies 2 and 3) followed
the theory of deliberate practice stating that expertise is the result of specific and intense practice extended for a minimum of ten years (Ericsson, Krampe, & Tesch-Römer, 1993) and provides a new paradigm in sports research called the specialization paradigm. It compares experts with about the same number of years of experience but with different kinds of experience (Bilalić, McLeod, & Gobet, 2009). In addition, the importance of differentiating between experts in team and individual sports is shown by an argument of Hastie and Dawes (2010) who say that “in nonreactive, uniform-playing-field sports, subtle sequential dependencies manifest themselves in performance; in chaotic, in-your-face, player-on-player reactive sports, there are no such patterns” (pp. 145–146).

**General Method**

**Overview**

For all studies we used the following three-factorial design: It was a 2 (experience of participants) × 2 (length of the sequences) × 2 (perfection of the sequences) factorial design with repeated measures on the last two factors. All participants provided informed consent. All studies were approved of by the ethical committee of the authors’ university.

**Apparatus and Material**

The stimuli were presented on a 17” TFT computer monitor. The video clips used were the same in all studies and they were the same as those used in the Gula and Köppen (2009) study showing two volleyball players. The sequences of two volleyball players (Player A and Player B) were arranged in a way that the attacks of Player A were shown on the left side of the display, and the attacks of Player B were shown on the right side.

The videos displayed on the computer screen ended either in a hit (defined as a smash into the opponent’s field) or in a miss (defined as smash into the net, the block, or outside the field). After each attack the participant was informed about the outcome (hit or miss) to make sure that the situation was perceived correctly, especially in the cases of balls close to the sidelines. The software program recorded the option chosen by the participants (allocate the ball to Player A or Player B), and the decision time the participants needed for their decision.

The sequences of players were distributed as ecologically validly as possible by showing realistic performances based on the sequences of successful hits and misses found for two players in the TopScorer database (a database of German First Division Volleyball containing the performances of players over several seasons). The Institute for Applied Training Science (IAT) in Leipzig, Germany provided us with the video clips of successful hits and misses of the two volleyball players. Every video clip showed the following situation: After the service of the opposing team, the playmaker received the ball and then allocated the ball to the left outside position where a player (either Player A when shown on the left or Player B when shown on the right side of the screen) hit or missed.

Four sets ending with 25 points (international volleyball rule) were presented. Each set consisted of 44 attacks (22 attacks by each player). Four conditions were
designed (one condition per set), manipulating the parameters “perfection” and “length” of a sequence:

1. Player A is hot, “short, perfect” condition (three hits in a row);
2. Player B is hot, “long, perfect” condition (four hits in a row);
3. Player A is hot, “short, imperfect” condition (four attacks with one miss);
4. Player B is hot, “long, imperfect” condition (five attacks with one miss).

Because of the 25-points rule it was not possible for both players to have the same base rate within a set. Therefore, the base rate differed by one point but alternated between the players from set to set, such that the total base rates were the same.

In Study 3, the context was changed from a hot hand to a cold hand. The manipulation of the cold hand sequences was identical to the hot hand manipulation by replacing sequences of hits with sequences of misses, by having the same base rates of the presented players, and by keeping the factors length (short and long) and perfection (perfect and imperfect). (see Table 1)

**Procedure**

Participants were individually tested. A session took about 45 min. At the beginning of the session the investigator presented the participant with a written introduction to the experiment and the participant had to provide personal data. The participant was instructed to watch the video clips and to make allocation decisions after each clip, either to Player A or to Player B. After reading the instructions, the participant warmed up for the test by observing four pilot video clips and pressing the button corresponding to the player (button “A” for Player A and button “B” for Player B) to make an allocation decision. Four sets of a volleyball game were presented. Each set consisted of 44 attacks (22 attacks by each player) until 25 points. In the end the participant had to state if he believed in the hot hand (cold hand) using a scale from 1 to 6 (1 = strongly against, 6 = strongly in favor). We presented the participants definitions of the hot hand and the gambler’s fallacy. For identifying confounding factors we used a scale from 1 to 6 (1 = low motivation/comprehension, 6 = high motivation/comprehension) to measure the motivation and task comprehension.

**Data Analyses**

In our studies we analyzed how athletes with different kinds and levels of expertise measured by years of experience perceive and act on hot and cold hands. We focused on the following dependent variables: the number of allocations to the hot/cold player, the decision time (measured in milliseconds), the conditional probabilities of the allocations to the hot/cold player, and the autocorrelation of the allocation sequences.

A post hoc analysis of the expertise-based allocation behavior of the Gula and Köppen (2009) study computed an achieved power of .74, with a sample size of 20 participants and $d = .38$. In our three studies we used 24 participants for each study, expecting a similar effect. For all three studies we conducted post hoc analyses to compute the achieved power. The power values concerning the allocation behavior of the participants range from .71 in Study 1 to .81 in Study 2 (Study 3 showed an achieved power of .78).
Table 1  A Sample Sequence of Outcomes (hits = H, misses = M) Showing 22 Attacks With a Hot Hand of Player B in the Condition “Short, Perfect”

<table>
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<tr>
<td>Player A</td>
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<td>Player B</td>
<td>M</td>
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</table>
For the effect sizes concerning \( F \)-tests we used partial \( \eta^2 \) statistic (\( \eta_p^2 \)); only effect sizes for \( F \) values > 1 were reported. According to Cohen (1988, p. 283), we distinguished between small (\( \eta^2 = .0099 \)), medium (\( \eta^2 = .0588 \)), and large (\( \eta^2 = .1379 \)) effect sizes. For the effect sizes concerning \( t \) tests we used Cohen’s \( d \) statistic; we distinguished between small (Cohen’s \( d = .20 \)), medium (\( d = .50 \)), and large (\( d = .80 \)) effect sizes.

Calculating the conditional probabilities of the allocations concerning hits after hits and hits after misses and comparing them with each other was a measure for hot hand behavior (or cold hand behavior). To identify hot (cold) hand behavior, the conditional probability of an allocation to the player having performed “hit after hit” (“miss after miss”) must be higher (lower) than the conditional probability of an allocation to the player having performed “hit after miss” (“miss after hit”). An autocorrelation is another measure of hot hand behavior, counting the correlations of successive events, such as allocations to the hot player. A lag-1 autocorrelation correlates the original sequence with itself moved by one position. In the case of a positive autocorrelation, there is evidence of a hot hand because of systematic repetitions.

**Study 1**

**General Sports Experience in a Hot Hand Environment**

The purpose of Study 1 was to show whether general sports experience had a smaller influence on making allocations to the hot player than sport-specific experience did. Therefore, our study was based on the experimental design of the Gula and Köppen study (2009), which analyzed volleyball-specific novices and experts in a hot hand environment.

**Participants**

The participants (\( N = 24 \), females = 8) were all sport students between the ages of 19 and 30 years (\( M = 23.87, SD = 3.35 \)) and they were distributed into two groups based on their general sports experience: experts (\( n = 12 \)) and beginners (\( n = 12 \)). General experience in sports was measured by years of practice. The experts had an average practical experience of 13.45 years (\( SD = 4 \)) and practiced in a club at regional level. The beginners had practical experience of 4.28 years (\( SD = 2.08 \)) and were all recreational athletes. The participants had no experience in volleyball.

**Results**

In this study we wanted to know whether general sports experience had an influence on playmakers’ decision making in a hot hand environment. First we tested whether players allocated more balls to the hot hand player. A one-sample \( t \) test against equal distribution (if number of allocations was significantly greater than 22, which would be the equal allocation of 44 balls) shows that both groups were similarly influenced by hot hand sequences, allocating significantly more balls to the hot player compared with equal distribution, \( t(23) = 4.49, p < .001, d = .91 \). On
average experts and beginners allocated 24.57 balls \((SD = 2.81)\) to the hot player in each condition (for an overview of the allocations see Figure 1). The above-average number of allocations to the hot player can be explained by the hot hand belief of the participants. Only one beginner mentioned that he did not believe in the hot hand (“1” on the scale); the other participants stated a strong belief (“6” on the scale).

The three main effects “general sport experience” (between-subject effect), “length of the hot hand sequence,” and “perfection of the hot hand sequence” (within-subject effects) were not significant: general sport experience, \(F(1, 22) = 1.08, p = .311, \eta_p^2 = .047\) (achieved power .54). A 2 (experience) × 2 (length of the sequence) × 2 (perfection of the sequence) analysis of variance (ANOVA) revealed no significant two-way or three-way interactions: Length × Perfection, \(F(1, 22) = 3.1, p = .092, \eta_p^2 = .124\) (achieved power .54). The effects show that there is no significant difference between experts and beginners concerning the allocation distribution between the players (independent \(t\) test, \(d = .42\)).

From set to set both groups showed an increase in speed of deciding whom to allocate the ball to. However, there was no significant difference (independent \(t\) test, \(d = .60\)) between the experts \((M = 3.74\) s, \(SD = 1.67)\) and the beginners \((M = 4.73\) s, \(SD = 1.59)\). A speed–accuracy test of allocation decisions and decision time showed that time and quality were uncorrelated, and therefore, these variables will be analyzed separately. The test revealed a near zero correlation of experts and beginners \((r = .03, p = .24)\).\(^1\) The measure for quality is the number of correct allocation decisions the participants made. A correct allocation decision was defined as a “win-stay lose-shift” strategy, meaning that the participant was meant to allocate the ball to the player who actually was successful, or stop allocating the ball to the player who actually missed. According to this definition of correct, the experts made 55.05\% correct decisions and the beginners 50.56\% correct decisions. Thus, the experts were better, but an independent \(t\) test of the number of correct decisions revealed a nonsignificant difference.

Table 2 presents the conditional probabilities of the allocations to the hot player based on his previous performance on the one hand, and on the other hand the lag-1 autocorrelation. Six conditions of sequential hits and misses are shown.

Both experts and beginners showed hot hand behavior—that is, allocation to the hot hand player even when the base rates of the displayed players were identical. After a successful attack of the hot player the probability of allocating the next ball to him was significantly higher than 50\% \((p < .05)\). In the case of four hits in a row, the beginners allocated the ball to the hot player with the highest probability of even 83\%, whereas the experts showed the highest tendency after two hits in a row with a probability of 74\%. This indicates a stronger influence of the hot hand sequences on the beginners, which is also revealed by the autocorrelations of the allocation sequences.

The lag-1 autocorrelation revealed that beginners were more stable in their decisions than experts, proven by a higher and a significantly positive correlation \((r = .29, p < .05)\), indicating that the allocations to the hot player were not made randomly, but systematically.

**Discussion**

The goal of Study 1 was to compare general sports experience with sport-specific experience. It was shown that experts and beginners perceived hot hand streaks
and used them as cues for their allocation decisions. Compared with the results of the previous study (Gula & Köppen, 2009), the same hot hand effect was detected. The influence of hot hand sequences resulted in more allocations to the hot player than to the other player, but in the current study without significant interactions of experience, length, or perfection. Due to the similar test power calculated, we concluded that the missing significance lay in the different experience of the participants. People with sport-specific experience seem to be influenced differently compared with people with general sports experience lacking experience in volleyball. Another reason for the difference between the studies could be the experience differences within the groups of participants. Gula and Köppen (2009) analyzed sport-specific experts and novices and in this study we investigated general sport experts and beginners. To exclude this confounding factor, we only concentrated on experts in the following studies, using the specialization paradigm.

The decision time differences can be explained due to the higher skill level of the experts, but the results only partly reflect realistic allocations, so these effects warrant further investigation. The smaller autocorrelation of the experts indicates a more frequent alternation of allocations to the volleyball players. A reason could be a stronger focus of the experts on the equal base rates of the players, which is based on their higher level of expertise.

We know now that experts and beginners with general sports experience are influenced by hot hand sequences. As mentioned above, it is necessary to analyze different expert groups with similar experience in years but with different skill levels (specialization paradigm). Therefore, we investigated whether experience in different kinds of sports is also influenced by hot hand sequences. The factor sport-specific experience was split into “individual athletes” and “team athletes” because these athletes possessed the required “expertise background” (concerning the specialization paradigm). First, we predicted that both individual and team sport experts would also be influenced by hot hand sequences, allocating more balls to the hot player (as shown in Study 1 for general sports experts). The second prediction was that individual athletes would be more strongly influenced than team athletes, due to the external factors of team sports (e.g., teammates) and the stronger perception of the reciprocal relationship between self-efficacy and positive performance.

**Study 2**

**Sport-Type-Specific Experience in a Hot Hand Environment**

For direct comparison with Study 1 we used the same design. We specified the experience of the participants in this study by subdividing this factor into the sport-type categories “individual athletes” and “team athletes.” This differentiation is important due to the influencing factors within individual and team sports (Hastie & Dawes, 2010; Oskarsson et al., 2009).

**Participants**

The participants ($N = 24$, females = 10) were all sport students between the ages of 19 and 33 years ($M = 23.91$, $SD = 3.42$), and they were assigned to two groups...
by personal information: team athletes \((n = 12)\) and individual athletes \((n = 12)\). Experience in sports was measured by the amount of years the participant had practiced in a club at regional level. The individual athletes had an average of 11.83 years’ \((SD = 2.17)\) experience, and the team athletes had practical experience of 12.46 years \((SD = 1.86)\). The participants had no experience in volleyball and were different from those in Study 1.

**Results**

In this study we wanted to detect whether sport-type-specific experience also has an influence on playmakers’ decision making in a hot hand environment, as shown in Study 1. The three main effects “sport-type-specific experience” (between-subject effect), “length of the hot hand sequence,” and “perfection of the hot hand sequence” (within-subject effects) were calculated, and showed a significant effect of perfection, \(F(1, 22) = 6.77, p = .017, \eta_p^2 = .244\). No significant effect was shown for length, \(F(1, 22) = 2.77, p = .111, \eta_p^2 = .117\) (achieved power .55). The 2 (experience) \(\times\) 2 (length of the sequence) \(\times\) 2 (perfection of the sequence) ANOVA revealed no significant two-way or three-way interactions (Experience \(\times\) Length \(\times\) Perfection: \(F(1, 22) = 1.05, p = .318, \eta_p^2 = .047\), achieved power .55).

Both individual and team athletes were influenced by the hot hand sequences, and allocated significantly more balls to the hot player, \(t(23) = 5.74, p < .001, d = 1.19\). There was no significant difference between individual and team athletes (independent \(t\) test, \(d = .18\)). On average, 24.5 allocations \((SD = 2.12)\) were made to the hot player per set—nearly the same as in Study 1 (see Figure 1). Looking at the belief of the participants, it can explain why significantly more balls were allocated to the hot player again. One team athlete was “strongly against the hot hand” (“1” on the scale), and another team athlete was “weakly against the hot hand” (“3” on the scale), whereas the rest of the team athletes were either “strongly in favor of the hot hand” (seven chose “6” on the scale) or “quite strongly in favor of the hot hand” (three chose “5” on the scale). The individual athletes showed a similarly strong belief in the hot hand. Only one of them was “strongly against the hot hand” (“1” on the scale), and the remaining participants were “strongly in favor of the hot hand” (“6” on the scale). A correlation of the belief and the allocations to the hot player showed that team players only partly relied on their belief for making allocation decisions \((r = .27, p = .42)\).

From set to set both groups showed an increase in speed of deciding whom to allocate the ball to. However, there was no significant difference (independent \(t\) test, \(d = .81\)) between the team athletes \((M = 3.04 s, SD = .49)\) and the individual athletes \((M = 3.92 s, SD = 1.47)\). A speed–accuracy test was conducted; analyzing the correlation of allocation decisions to the hot player and the decision time the team and individual athletes needed. The correlation for all athletes was nonsignificantly close to zero \((r = -.03, p = .41)\), showing that decision time and quality were uncorrelated; therefore these variables were separately analyzed. The individual athletes made 51.44% correct decisions, and the team athletes allocated the ball correctly for 54.68% of the decisions. There was no significant difference between the sport type experts.

Table 2 presents the conditional probabilities of the allocations to the hot player based on his previous performance. The same six conditions of sequential
hits and misses as in Study 1 are shown. Once again a lag-1 autocorrelation was conducted (see Table 2).

As already shown in Study 1, we detected that conditional probabilities for allocations to the hot player were higher after hits than after misses, providing evidence of hot hand behavior for team and individual athletes. After a hit by the hot player the participants always tended to allocate the next ball to him (probability higher than 50%), and in the case of three hits in a row the probability was higher than 80% for individual as well as team athletes.

The lag-1 autocorrelation detected no differences between the two expert groups, showing a nearly identical and nonsignificant correlation around zero (see for details Column 7, Table 2). This indicates similar hot hand behavior for both team and individual athletes, which seems to be strongly influenced by the equal base rates of the players.

Discussion

The goal of Study 2 was to focus on the influence of sport-type-specific experience on playmakers’ decision making in volleyball, in respect of hot hand sequences. Therefore, expert athletes were subdivided into groups according to sport type: team sport or individual sport. Both groups perceived the hot hand of a player and used it as cue for their allocation decisions. Contrary to our hypothesis, the team athletes allocated even more balls to the hot player than the individual athletes did, but this difference was nonsignificant. This was unexpected because individual athletes should be influenced by individual positive performance more than team athletes, as overachieving teams are frequently characterized by a togetherness that overshadows any individual performer (Feltz & Lirgg, 2001).

Team athletes needed less time for their allocation decisions than the individual athletes, and we suggest that this finding is based on the sport context. Team athletes are more familiar with the environment and structure of a team sport, resulting in them needing less time to make allocation decisions. As argued before, decision time in an experimental situation only partly reflects a realistic game situation because of its temporal structure.

The nearly identical autocorrelations of both groups around zero showed that both types of sport experience (individual and team) lead to alternating allocation sequences. One might think that team athletes would vary their allocation decisions more extensively than individual athletes, as they should recognize the importance of preventing the opponent from reliably predicting to whom the next ball will be allocated. In contrast to the experts in Study 1, the team and the individual athletes allocated the ball to the hot player after three hits in a row.

We now know the effects of sport-type-specific experience on playmakers’ decision making in a hot hand environment. This leads to the question of what happens in a cold hand environment. Therefore, in the following study, the factor sport-type-specific experience was analyzed using a cold hand scenario in volleyball. We predicted that both individual and team experts would allocate fewer balls to the cold player inverted to the hot hand behavior (seen in Studies 1 and 2), and that individual athletes would be more strongly influenced by cold hand sequences than team athletes because choking is attributed to the individual (Jordet, 2009).
Study 3

Sport-Type-Specific Experience in a Cold Hand Environment

The purpose of Study 3 was to analyze the influence of sport-type-specific experience on allocation decisions in volleyball in the context of cold hand sequences to contrast the results with those of the previous studies. Because of the independent variable “sport-type-specific experience” (individual athletes vs. team athletes), it was necessary to use a between-subject design following the specialization paradigm.

Participants

The participants ($N = 24$, females = 3) were all sport students between the ages of 20 and 30 years ($M = 24.33$ years, $SD = 2.44$), and they were distributed into two groups by personal information: individual athletes ($n = 12$) and team athletes ($n = 12$). Their sports experience was measured by years of practice in a club at regional level. The individual athletes had an average of 15.62 years’ ($SD = 3.01$) practical experience, and the team athletes had an average practical experience of 13.17 years ($SD = 2.74$). The participants had no experience in volleyball and were different from those in Studies 1 and 2.

Results

In this study we transferred the hot hand conditions of the previous studies to a cold hand context. We wanted to know whether sport-type-specific experience also has an influence on playmakers’ decision making in a cold hand environment. The three main effects “sport-type-specific experience” (between-subject effect), “length of the hot hand sequence,” and “perfection of the hot hand sequence” (within-subject effects) were calculated, showing a nonsignificant effect, $F(1, 22) = 3.31, p = .082, \eta^2_p = .131$ (achieved power .54). The $2 \times 2 \times 2$ ANOVA revealed no significant two-way or three-way interactions.

Similar to the results of Study 2 using the hot hand environment, sport-type-specific experience influenced playmakers’ decision making in the cold hand environment, resulting in less allocations to the cold player (independent $t$ test, $d = .22$). Both individual and team athletes allocated significantly fewer balls to the cold player compared with equal distribution, $t(23) = -8.39, p < .001, d = 1.71)$. On average, 19.4 allocations ($SD = 1.5$) were made to the cold player per set, showing a reversed effect compared with the hot hand environment (for an overview of studies’ results see Figure 1).

Both groups showed an increase in speed of deciding to whom to allocate the ball. However, there was no significant difference (independent $t$ test, $d = .31$) between the team athletes ($M = 3.94$ s, $SD = 2.17$) and the individual athletes ($M = 4.23$ s, $SD = 2.71$). The speed–accuracy test for the cold hand environment showed similar results to the hot hand environment—a close to zero correlation of time and quality of the decisions ($r = .09, p = .37$). The success rate of the individual
athletes was 51.12% vs. 50.09% of the team athletes. An independent $t$-test of the number of correct decisions showed no significant differences between individual and team athletes regarding the cold hand. The belief of the participants cannot explain this difference because everyone stated a strong belief in the cold hand ("6" on the scale).

Table 2 presents the conditional probabilities of the allocations to the cold player based on his previous performance. As in Studies 1 and 2, six conditions of hits and misses in a row are shown, but this time in a cold hand context. In addition, a lag-1 autocorrelation was conducted (see Table 2).

The conditional probabilities indicate cold hand behavior of the team as well as the individual athletes because of the low allocation probabilities concerning several misses in a row. After a miss of the cold player the participants tend to rather allocate the ball to the other player which is indicated by the probabilities of less than 50% in the cases of two, three, and four misses in a row—the lowest probability reaches even 31%. In case of two hits in a row both groups show the highest probability of allocating the ball to the cold player, whereupon the individual athletes even reach a probability of 65%.

A lag-1 autocorrelation (Column 7 in Table 2) revealed a lower and negative autocorrelation for team athletes, but both autocorrelations were nonsignificantly close to zero. This indicates that the allocation decisions of both team and individual athletes were made alternately again, which is also reflected by about the equal number of correct and incorrect decisions.
<table>
<thead>
<tr>
<th></th>
<th>$P(\text{allocation to hot player/hit})$</th>
<th>$P(\text{allocation to hot player/2 hits})$</th>
<th>$P(\text{allocation to hot player/3 hits})$</th>
<th>$P(\text{allocation to hot player/4 hits})$</th>
<th>$P(\text{allocation to hot player/miss})$</th>
<th>$P(\text{allocation to hot player/2 misses})$</th>
<th>Lag-1 autocorrelation</th>
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<td>.74</td>
<td>.73</td>
<td>.63</td>
<td>.52</td>
<td>.51</td>
<td>.06</td>
</tr>
<tr>
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<td>.65</td>
<td>.71</td>
<td>.79</td>
<td>.83</td>
<td>.46</td>
<td>.43</td>
<td>.29*</td>
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<tr>
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<td>.82</td>
<td>.76</td>
<td>.56</td>
<td>.57</td>
<td>-.03</td>
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<tr>
<td>Individual athletes</td>
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<td>.74</td>
<td>.81</td>
<td>.69</td>
<td>.59</td>
<td>.48</td>
<td>.04</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>$P(\text{allocation to cold player/miss})$</th>
<th>$P(\text{allocation to cold player/2 misses})$</th>
<th>$P(\text{allocation to cold player/3 misses})$</th>
<th>$P(\text{allocation to cold player/4 misses})$</th>
<th>$P(\text{allocation to cold player/hit})$</th>
<th>$P(\text{allocation to cold player/2 hits})$</th>
<th>Lag-1 autocorrelation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team athletes</td>
<td>.54</td>
<td>.36</td>
<td>.43</td>
<td>.31</td>
<td>.52</td>
<td>.56</td>
<td>-.05</td>
</tr>
<tr>
<td>Individual athletes</td>
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<td>.52</td>
<td>.54</td>
<td>.45</td>
<td>.59</td>
<td>.65</td>
<td>.08</td>
</tr>
</tbody>
</table>

*p < .05
Discussion

The goal of Study 3 was to detect whether cold hand sequences lead to the opposite effect of hot hand sequences, resulting in fewer allocations to the cold player. In addition, the influence of sport-type-specific experience on playmakers’ decision making was analyzed. Results suggest that team and individual athletes both perceived the cold hand of a player and used it for their allocation decisions.

In the cold hand environment the volleyball player with the cold hand received fewer allocations than the other volleyball player. The individual athletes allocated fewer balls to the cold player than the team athletes did. This fact partially supports our hypothesis of choking, showing that individual athletes took the negative sequences more into account and believed that the negative performance will continue. Team athletes were influenced by their team experience, which has taught them that individual performance in a team sport can be assisted by the teammates. As in Study 2, the team athletes needed less time for their decisions, indicating that team athletes can perceive the environmental structure of a team sport better than individual athletes.

Summary and Concluding Discussion

The rationale of this set of studies was to analyze the effects of expertise (measured by years of experience) on playmakers’ decision-making in a hot and cold hand environment. We conducted three studies, investigating general sports experience in a hot hand environment first, sport-type-specific experience in a hot hand environment second, and sport-type-specific experience in a cold hand environment last. In the current studies we showed that experience influences the playmakers’ decision-making process, resulting in more allocations to the hot player in a hot hand environment, and respectively, fewer allocations to the cold player in a cold hand environment. Hence, sensitivity to streaks is independent of the environment.

We know now that athletes are sensitive to streaks in general and use them for their allocation decisions. This sensitivity can be explained by the predominating belief of the participants that was shown in all three current studies. Because of the similarly strong beliefs of nearly all participants this factor is not useful for explaining the differences we found between the experts. More so, the different classes (Study 1) and kinds of experience (Study 2 and Study 3) seem to be more valid candidates to explain behavioral differences. A new result, not reported in the literature yet, is that experts are more sensitive to negative sequences (a cold hand of a player in Study 3) than to positive sequences (a hot hand of a player in Study 2).

Carlson and Shu’s (2007) rule of three seems to have been used by a large group of the participants, as the hot volleyball player with three or four hits in a row received more allocations than the other player. But the conditional probabilities showed that the individual athletes in Study 2 were more strongly influenced by two hits in a row than the team athletes. Relating the allocation behavior of the participants to underlying strategies, it can be found, according to Tyszka et al. (2008), that mostly momentum strategies were used by all groups of experts. Interestingly, neither team nor individual athletes switched to contrarian strategies in the cold hand environment.
These results could have practical implications, showing coaches that cold players can be replaced because most teammates will not allocate the ball to them. The momentum strategy of the teammates can inform the opponents, who can then reliably predict future actions and create appropriate tactical arrangements.

Our studies showed that all experts detected streaks independent of their level of expertise measured by years of experience. The reasons for streak detection can be phylogenetic, as shown by Wilke and Barrett’s evolutionary approach (2009) that indicates that people have an inborn competence for detecting and using streaks based on a cognitive adaptation to the environment. Furthermore, streak detection could be ontogenetic as a result of behavioral development (a development inchoate with the birth—streaks occur everywhere in life, such as seven rainy days in a row), resulting in momentum and contrarian strategies (Tyszka et al., 2008). Experiences can also influence the perception of streaks as a result of human learning, as shown by Carlson and Shu’s (2007) rule of three. Streaks in sport have always enthused (hot hand) or shocked (cold hand) all kinds of people who watch or participate in sports. The hot and cold hand research has the potential to inform and to unite fans, coaches, athletes, and bettors by showing them that the belief in streaks and the behavior based on this belief are not fallacies, but a psychological phenomenon that has amazed the world since the birth of sports competitions.

As previously mentioned, the studies contained some limitations. The presented volleyball situation does not reflect the full complexity of a real game situation, as the number of options was constrained to two, and there was no time pressure. In addition, only two cues—hot/cold hand information and base rate of the volleyball players—were presented, and the base rate was constant within each study. We are aware of some result differences to previous research that need further attention in future work. For instance, Larkey et al. (1989) found shooting streaks in basketball if imperfect shot sequences of different lengths were considered. This finding in real data were manipulated in an experiment in which volleyball players’ allocations to the hot hand player were based on an interaction of the length of a sequence and its perfectionism (Gula & Köppen, 2009). In the current set of studies we could not replicate these interactions (but see Study 2 for an effect of perfection of the sequence). Due to these inconsistent results, we conclude that the hot hand belief is robust in different sports and among different experiences in sports. Whether a general perception of streaks in births, weather, the stock market, players’ performances, game outcomes, or roulette is influenced by situational factors warrants further investigation excluding the abovementioned limitations before recommendations can be made for athletes or coaches. These studies have built a fundament for further extended research to constitute benefits for scouting and developing tactics in sport.

Notes
1. The correlations of both groups run independently were also nonsignificantly close to zero.
2. The correlations run independently for each group were also nonsignificantly close to zero.
3. The correlations run independently for each group were also nonsignificantly close to zero.
4. About 94% of the participants declared a hot or cold hand belief. The belief–behavior correlation shows—where possible—that the experts relied on their belief for making allocation decisions.
References


