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# Perceiving Affordances in Sports through a Momentum Lens

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**Abstract**

In this experimental study, we tested whether athletes' judgments of affordances and of environmental features vary with psychological momentum (PM). We recruited golf, hockey, and tennis players, who were assigned to a positive or negative momentum condition. We designed a golf course on which participants made practice putts, after which they were asked to place the ball at their maximum "puttable" distance and to judge the hole size. Next, participants played a golf match against an opponent, in which the first to take a lead of 5 points would win the match. Participants were told that they could win a point by making the putt or by being closest to the hole. They wore visual occlusion goggles to prevent them from seeing the actual result, and the experimenter manipulated the scoring pattern to induce positive or negative PM. Participants in the positive momentum condition came back from a four-point lag to a four-point lead, whereas those in the negative momentum condition underwent the opposite scenario. We then asked the participants again to indicate their maximum puttable distance from the hole and to judge the hole size. After the manipulation, participants judged the maximum puttable distance to be longer in the positive momentum condition and shorter in the negative momentum condition. For the hole-size judgments, there were no significant effects. These results provide first indications for the idea that athletes' affordances change when they experience positive PM compared to negative PM. This sheds a new light on the dynamics of perception-action processes and PM in sports.

*Keywords:* Action possibilities, Action-specific perception, Golf, Perception-action, Psychological momentum

## 1. Introduction

Psychological momentum (PM) is the experience that things are going your way (positive PM), or that things are turning against you (negative PM). In sports, PM typically develops when moving toward or away from a desired outcome, such as the victory in a match (e.g., Adler, 1981; Den Hartigh, Gernigon, Van Yperen, Marin, & Van Geert, 2014; Gernigon, Briki, & Eykens, 2010; Markman & Guenther, 2007; Vallerand, Colavecchio, & Pelletier, 1988). This movement elicits various psychological and behavioral changes on the side of the athlete (e.g., Den Hartigh, Gernigon et al., 2014; Gernigon et al., 2010; Vallerand et al., 1988). A notable observation based on recent research is that positive and negative PM include positive and negative shifts in athletes' momentary abilities (e.g., Iso-Ahola & Dotson, 2014, 2016) and the perception of abilities to perform successfully (Den Hartigh, Gernigon et al., 2014; Den Hartigh, Van Geert, Van Yperen, Cox, & Gernigon, 2016; Iso-Ahola & Dotson, 2016). Interestingly, abilities are a key ingredient of the concept of affordances, which are the action possibilities for organisms (e.g., Chemero, 2003; Gibson, 1979; Turvey, 1992; Warren, 1984). Indeed, affordances are defined by the relation of environmental features and the abilities of the organism.

The current study aims at taking a first step in exploring the possible relation between PM and affordances. In the next sections we will discuss the theory of affordances, and elaborate on changes in affordances and judgments of environmental features when athletes' abilities change. Then, we will address the possible link between PM and affordances and present our research question: Are athletes' judged affordances and judged features of their performance environment affected by positive and negative PM?

### *1.1 Affordances in sports*

The theory of affordances may provide an important perspective to better understand successful performance in sports (cf. Araújo & Davids, 2009; Fajen, Riley, & Turvey, 2008).

Indeed, critical for successful performance in sports is that athletes successfully perceive and act upon the possibilities for action in their environment. Such possibilities for action can be, for instance, a pass that is reachable or unreachable for a soccer or hockey player, a car or motor that is overtakeable or not for a Grand Prix driver, a fly ball that is catchable or uncatchable for a baseball player, and so forth (e.g., Fajen et al., 2008; Oudejans, Michaels, Bakker, & Dolné, 1996; Postma, Lemmink, & Zaal, in press). These possibilities for action are typical *affordances* for athletes (e.g., Gibson, 1979; Fajen et al., 2008; for a review, see Barsingerhorn, Zaal, Smith, & Pepping, 2012). In sports situations, affordances appear and disappear as games and races evolve over time. Therefore, an important challenge in sport psychology research is to get a grip on the dynamics of these affordances (e.g., Araújo & Davids, 2009; Fajen et al., 2008; Weast, Shockley, & Riley, 2011).

The relations between the athlete and his or her environment, and thereby the affordances, are individual-specific (Gibson, 1979). A fly ball that travels a particular distance may be catchable for a professional outfielder, but not for an outfielder who is less skilled. Accordingly, previous literature has defined affordances by (a) some dimension of the actor's body in relation to some feature of the environment (i.e., body-scaled affordances, such as the length of a high-jumper relative to the height of the bar), or (b) the abilities of the actor in relation to some feature of the environment (i.e., action-scaled affordances, such as the jumping ability of the athlete relative to the height of the bar, which makes it possible to jump over the bar or not, e.g., Chemero, 2009; Fajen, 2007; Fajen et al., 2008; Pepping & Li, 2000).

Given that environmental features in relation to the athlete's abilities determine his or her possibilities for action, a change in either the environment or abilities *ipso facto* affects the affordances. With regard to changes in the environment, for instance, a fly ball may be catchable for a baseball player for some time, until the wind suddenly catches the ball (cf. Fajen et al., 2008; Postma, Smith, Pepping, Van Andel, & Zaal, 2017). In more complex team sports, the affordance of passability (to a team member) changes through the movements of the players on the field: At one moment, a team member may be available, but the next moment a pass to that team member may be interceptable by an opponent (e.g., Fajen et al., 2008; Passos, Cordovil, Fernandes, & Barreiros, 2012). With regard to athletes' abilities, these are often considered as general and relatively fixed[1]. From the perspective of affordances, however, abilities are by definition dynamic and defined within the actor-environment relation (e.g., Chemero, 2003; Fajen, 2007; Fajen et al., 2008). This view on abilities is also embedded in the terminology (e.g., catch*ability*, reach*ability*, intercept*ability*). However, how affordances change under the influence of ability-related variables remains relatively unexplored.

*1.2 Affordances and ability changes*

Some empirical studies outside sports have shown that when abilities undergo change, actors' affordances also alter (e.g., Franchak & Adolph, 2014; Konczak, Meeuwsen, & Cress, 1992). For instance, in a study with pregnant women, Franchak and Adolph (2014) found that previously passable doorways became no longer passable over the course of pregnancy. Furthermore, the women's judgments of the possibility to squeeze through particular doorways matched their abilities to actually do so. In sports, a few studies also found that particular variables that may have an impact on abilities, such as fatigue, trait anxiety, or state anxiety, influence actors' (judged) affordances during single tasks (e.g., Bootsma, Bakker, Van Snippenberg, & Thloreg, 1992; Pepping & Li, 2000; Pijpers, Oudejans, & Bakker, 2007; Pijpers, Oudejans, Bakker, & Beek, 2006). For instance, Pijpers and colleagues (2006, 2007) manipulated fatigue and state anxiety in participants and showed that judged and actual reaching height on a climbing wall were lower when participants were fatigued or anxious.

[1] In the sports- and psychology literature, 'skills' instead of 'abilities' are commonly considered to be dynamic, domain-specific, and often acquired through practice (e.g., Ericsson, Krampe, & Tesch-Römer, 1993; Iso-Ahola & Dotson, 2016).

Although few studies have manipulated ability-related variables and gauged participants' affordances, a related literature on embodied perception more extensively studied the effects of changes in ability-related variables on judgments of environmental features (see Witt & Riley, 2014). These studies showed, for instance, how wearing a heavy backpack makes hills look steeper (Bhalla & Proffitt, 1999), or arousal makes balconies look higher (Stefanucci & Storbeck, 2009). In the domain of sports, comparable effects have been found based on Witt and colleagues' action-specific perception account (Philbeck & Witt, 2015; Witt, 2011). According to this account, people perceive the environment in terms of their ability to act in it. For instance, researchers have shown that baseball players with a higher recent batting average reported a softball to be larger than players with a lower batting average (Witt & Proffitt, 2005), or that momentary golf performance has an effect on players' judged hole size (Witt, Linkenauger, Bakdash, & Proffitt, 2008). In the latter study, Witt et al. (2008) asked golf players after one round of golf to estimate the hole size. They found that those who played better judged the hole size to be bigger than players who did not play well. Many more examples of the manipulation of soft constraints affecting judgments of the physical properties of the environment can be found in this literature on embodied perception (e.g., Geuss, Cardell, & Stefanucci, 2016; Stefanucci, Gagnon, Tompkins, & Bullock, 2012; Zadra, Weltman, & Profitt, 2015) or action-specific perception (e.g., Witt & Dorsch, 2009; for overview articles, see Witt, 2011; Witt & Riley, 2014).

### *1.3 Linking affordances to psychological momentum*

Previous studies have demonstrated that PM comes with changes in anxiety, confidence, and other psychological and behavioral variables related to sports performance (e.g., Briki, Den Hartigh, Bakker, & Gernigon, 2012; Briki, Den Hartigh, Hauw, & Gernigon, 2012; Gernigon et al., 2010; Jones & Harwoord, 2008; Moesch & Apitzsch, 2012; Redwood-Brown, Sunderland, Minniti, & O'Donoghue, in press; Taylor & Demick, 1994). The experience of PM, as noted earlier, develops when moving toward or away from a desired outcome. Interesting for the present purpose is that studying PM carries the advantage that it can be manipulated in a straightforward way, for instance by letting athletes move toward or away from a desired victory.

Research increasingly suggests that, among the variables involved in PM, momentary ability levels and ability attributions are changing when athletes experience a positive or negative momentum scenario in a match (e.g., Den Hartigh, Gernigon et al., 2014; Iso-Ahola & Dotson, 2016). For instance, in their empirical study Den Hartigh and colleagues (2014) had rowing dyads compete against a virtual opponent. The race was displayed on a screen, and the researchers manipulated the race in a way that in one race the dyad came back from a six seconds lag and took a lead of six seconds (positive momentum scenario), whereas in another race they underwent the exact opposite (negative momentum) scenario. During these positive and negative momentum scenarios the dyads displayed positive and negative changes in their feelings of cohesion and efficacy (their estimates of their abilities to win the race), respectively. These negative psychological changes in the negative momentum scenario were stronger than the positive changes in the positive momentum scenario, a tendency that has also been found in individual sports (Briki, Den Hartigh, Markman, Micallef, & Gernigon, 2013; Den Hartigh & Gernigon, in press; Gernigon et al., 2010). Furthermore, compared to the positive momentum scenario, Den Hartigh, Gernigon et al. (2014) found that the dyads' exerted efforts decreased more rapidly in the negative momentum scenario, and the coordination between the rowers' actions was worse.

Although the research described above provided indications that the momentary ability (attribution) of athletes changes during positive and negative PM, previous studies only examined these changes by asking participants to respond to questionnaire items or by measuring their efforts in isolated experimental situations (e.g., Briki et al., 2013; Den

Hartigh, Gernigon et al., 2014; Den Hartigh et al., 2016; Perreault, Vallerand, Montgomery, & Provencher, 1998). In many sports, however, athletes need to perform in situations in which perception-action processes are key, and in which they are acting on affordances (Araújo & Davids, 2009; Fajen et al., 2008). Building upon previous research in the domains of PM, affordances, and action-specific perception, the present study set out to investigate if changes in PM can be linked to changes in affordance judgments and judgments of metrical environmental features.

### *1.4 The current study*

In this study, we aimed to answer the following research question: Are athletes' judged affordances and judged features of their performance environment affected by positive and negative PM? In order to answer this question, the research design should allow to (a) manipulate PM in positive and negative directions (b) measure the judgment of an affordance, and (c) measure the judgment of an environmental feature. One way to measure judged affordances is by determining actors' judged action boundaries, that is, the critical points at which an action can be successfully sustained (cf. Bootsma et al., 1992; Warren, 1984). Accordingly, we designed a golf-experiment in a controlled setting, and we tested whether participants' maximum judged distance from where they could make a putt (i.e., the judged affordance of "puttability") changed in a positive or negative momentum scenario. In addition, in line with the action-specific perception account, we examined whether participants judged an environmental feature (i.e., hole size) differently during positive or negative momentum (cf. Witt et al., 2008).

In accordance with the idea that PM changes athletes' momentary affordances, our first hypothesis was that participants judge the maximum puttable distance as relatively further from the hole in a positive momentum scenario than in a negative momentum scenario. In line with the idea that people perceive the environment in terms of their current ability to act in it (e.g., Witt, 2011; Witt & Riley, 2014), our second hypothesis was that participants perceive the hole to be relatively bigger in a positive momentum scenario than in a negative momentum scenario.

## 2. Method

### *2.1 Participants*

In total, twenty-three athletes participated in the study. Ten of these participants were golf players. Because the number of available golf players in the region was low, we also recruited eight national-level hockey players and five national-level tennis players with experience in playing golf. After the manipulation check, three participants had to be excluded for further analysis.[2] The remaining sample consisted of 13 males and seven females, among which were eight golf players, eight hockey players, and four tennis players. Their average age was 31.3 years (*SD* = 13.2). Participants did not receive a monetary incentive for participating, but we gave them a small gift after their participation. The protocol of the study was approved by the ethics committee of the host institution.

### *2.2 Experimental setup and procedure*

We conducted the experiment in a large room at a local sports club (see Figure 1 for the experimental setup). The setup consisted of two indoor golf lanes on artificial turf with putting cups (i.e., the holes). The lanes were partly separated by a portable wall, and in between the two lanes, we placed a 27" HD screen that displayed and updated the score in the momentum session (details of this session will follow in section 2.2.2). In addition, we used the following equipment for the participants: A golf club (participants were also allowed to bring their own), a golf ball, Plato liquid-crystal (LC) goggles (Translucent Technologies, Canada), ear plugs, and soundproof headphones. In the LC goggles, the glasses could be

[2] Ten participants in the positive momentum condition indicated they were moving toward the *victory* in the second part of the match, and ten participants in the negative momentum condition indicated they were moving toward the *defeat* in the second part. The other three participants indicated that they had *not* noted such movements toward the victory or defeat in their match, therefore we could not assume that they experienced positive or negative PM due to the manipulation.

changed from transparent to opaque (and vice versa) within 3-5 milliseconds, by using a remote control. LC goggles are typically used to test and train visual control in sports (e.g., Oudejans, 2012; Oudejans et al., 1996). In the current study, these goggles were used to block the participants' vision directly after touching the ball with their club, so that we were able to manipulate the performance feedback while the participant remained unaware of the actual result of his or her action. The earplugs and the headphones were also used to block performance information, as the putting cup made a soft sound when the ball touched it. In this experimental setting, participants were consecutively involved in a baseline session, momentum session, and a posttest, which we will describe below (see Table 1 for an overview).

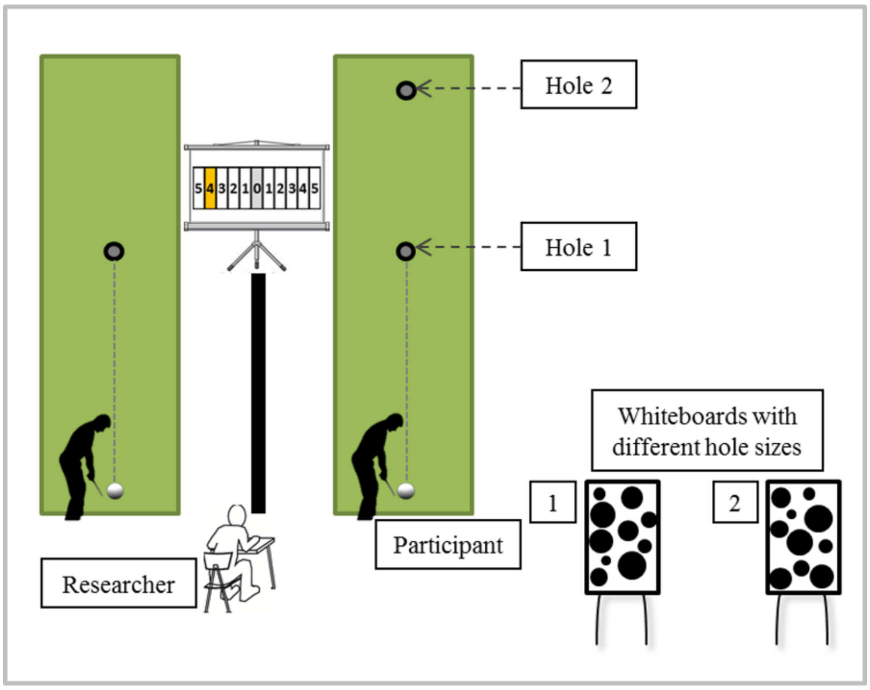


*Figure 1.* Experimental setup. Hole 1 corresponds to the target hole of the practice putts in the baseline session and the putts in the momentum session. Hole 2 was used to determine the maximum puttable distance in the baseline session and the posttest. Whiteboard 1 was used for the hole size judgment in the baseline session and whiteboard 2 was used for the hole size judgment in the posttest. The researcher controlled the LC goggles in the baseline- and momentum session, as well as the score on the screen in the momentum session.

Table 1.

*Overview of the Experimental Design*

| Condition | Phase 1 | Phase 2 | Phase 3 |
|---|---|---|---|
| Positive Momentum (N=10) | Baseline judgments puttability, hole size | Positive momentum manipulation | Posttest judgments puttability, hole size |
| Negative Momentum (N=10) | Baseline judgments puttability, hole size | Negative momentum manipulation | Posttest judgments puttability, hole size |

### *2.2.1 Baseline session*

The study started with a session to measure participants' baseline judgments. The researcher, research assistant and the confederate were present before the arrival of the participant. Upon his or her arrival, a research assistant brought the participant to a waiting room next to the experimental room, where he or she received a brief explanation about the research and signed the informed consent form. Then, the participant was taken to the experimental room where he or she met with the researcher. The researcher told the cover story that we were interested in the visual effects of after-putt feedback in golf and that we, therefore, made use of visual occlusion goggles in a competitive setting. Following this explanation, the researcher told the participant that he or she could first make five practice putts while wearing the LC goggles and the earplugs, to get used to the setting. These practice putts were made at 2 meters from hole 1 (see Figure 1). Before each practice putt the participant could see the hole, but right after touching the ball the goggles turned opaque, so that participants could never see the result of their putt. Each time the participant made the practice putt a research assistant collected the ball, and the researcher turned the goggles transparent again as soon as the research assistant had placed the ball back at the putting location.

After the practice putts, the researcher helped the participant to take off the LC goggles and took him or her to hole 2. The researcher asked the participant to place the ball at his or her maximum puttable distance from this hole, in order to determine the participant's baseline affordance judgment. The research assistant marked this distance with a coin. Then, the research assistant took the participant to whiteboard 1, including holes of different sizes, and asked him or her to judge the size of the hole in the lane. After this baseline measure of size judgment, the researcher asked the participant to go to the waiting room again so that his or her upcoming opponent could also practice for the match in the same setting. While the participant was in the waiting room, we used our time to prepare the momentum session; process the baseline measures (i.e., measuring the distance between the coin and the hole, and writing down the judged hole size); and prepare the confederate who would play against the participant.

*2.2.2 Momentum session*

After about 15 minutes, the participant was picked up by the research assistant again, to play the one-to-one putting match against an opponent (the confederate). We had several confederates at our disposal to ascertain that the participant and the confederate always had the same gender and did not know each other beforehand. This way we prevented false expectations about the outcome of the match. Before the match started, the researcher explained the participant and confederate that they would play a match against each other while wearing the LC goggles, earplugs, and headphones. They were told that the first to take a lead of 5 points on the opponent would win the match, and that the score would be visible on the screen in front of them. The experimenter explained that they scored a point when making the putt or when their ball was closer to the hole than that of the opponent. Moreover, the researcher explained that after 15 putts, in case there was no winner yet, they had to make a putt from another distance to recalibrate their brain and their vision, as this was repeatedly occluded during the match by the LC goggles. The latter explanation was made up, the actual reason for the break after 15 putts was that this was the moment to conduct the posttest measure of the affordance- and size judgments.

When participants were ready, the experimenter counted down from 3-to-1 and the participant made his or her first putt, again at a 2-meter distance from hole 1. When the participant's club touched the ball, the experimenter turned the goggles opaque; the research assistant quickly collected the balls and placed them back at the putting location; and the experimenter turned the goggles transparent again and updated the score on the screen. This score was manipulated in accordance with previous research on PM. More specifically, we built scenarios in which participants were exposed to a gradual evolution from negative to positive scores (positive momentum) or the other way around (negative momentum), which typically generates a positive or negative PM experience, respectively (e.g., Briki, Doron, Markman, Den Hartigh, & Gernigon, 2014; Den Hartigh & Gernigon, in press; Gernigon et al., 2010; Vallerand et al., 1988).

In the positive momentum condition, participants first lost 4 points, but then won point-after-point until they were 4 points ahead. In the negative momentum condition, the scoring scenario was the exact opposite. In order to keep the participants attentive to the (manipulated) scores, participants were either given a yellow or orange ball that corresponded to their color on the score board. After each putt, the score was visibly updated on the screen in front of the participant, and it was emphasized who won the point by simultaneously displaying a yellow or orange rectangle. When the participant had come back from -4 points to +4 points (positive momentum), or when he or she lost a +4 lead and had -4 points (negative momentum), the research assistant announced that the players had made 15 putts. Then, the posttest was conducted.

2.2.3. *Posttest and debriefing*

In the posttest the research assistant asked the participant again to place the ball at his or her maximum puttable distance from hole 2, and marked this with a coin. Subsequently, the participant was brought to whiteboard 2, and asked to point out the hole size that most accurately matched with the hole size in his or her lane. Following the measure of size judgment, the research assistant indicated that the participant could try to make the putt from his or her maximum puttable distance (most participants missed). Then, the assistant brought the participant and the confederate to the waiting room so that they could fill out a short questionnaire including manipulation checks. After they had completed the forms, the research assistant invited them back to the research room, where we debriefed the participant about the actual purpose of the study and asked them about their experiences.

*2.3 Measures*

The measure of the judged puttability (i.e., the judged affordance) was the participant's indicated maximum distance from the hole. We used a measuring tape to determine the distance in centimeters between the marker and the hole. In order to measure the size judgment, we used two whiteboards on which 11 black circles were pasted in a random configuration. The diameters of these circles varied between 6.8 and 15.8 cm, with one of them matching exactly with the diameter of the putting cup-hole (i.e., 10.8 cm). The circle corresponding to the correct hole size was set to 0; the five bigger circles were scored +1 to +5; and the five smaller circles were scored -1 to -5. The circles were arranged differently in the baseline session and the momentum session.

The manipulation check items were: *Was there a period in the match that you were moving toward the victory?*; *Was there a period in the match that you were moving toward the defeat?* These questions could be answered by "No" or "Yes, namely in the [indicate period of the match]". Given that athletes develop a PM experience when they perceive that they move toward or away from a desired outcome (the victory in this case), this check was necessary to determine whether participants could be included in the analyses.

*2.4 Data analysis*

Our design included two measures (baseline and posttest) and a momentum manipulation (between-subjects factor). Recent experimental research that compared positive and negative momentum conditions generally found large effect sizes (e.g., Briki, Den Hartigh, Markman, & Gernigon, 2014; Briki, Doron, et al., 2014; Den Hartigh, Gernigon et al., 2014; Den Hartigh et al., 2016). Taking our design and previous results into account, we determined the required sample size using the following input parameters: Effect size f = 0.4 (> .4 is considered as large according to Cohen's (1988) guidelines for behavioral sciences); α error probability = .05; Power (1-β error probability) = .8. This resulted in a required sample size of 16.

In our study we aimed to obtain participants with golf-experience, which provided a natural constraint on the number of participants that could be recruited. Although we recruited a large enough sample size according to the a priori power analysis, we took additional measures to improve the statistical power and interpretation of our results (cf. Schweizer & Furley, 2016). More specifically, we (a) conducted a statistical analysis (i.e., Monte Carlo permutation) that has higher statistical power than *t*-tests and *F*-tests in the case of relatively small sample sizes (e.g., Den Hartigh, Van der Steen et al., 2014; Ludbrook & Dudley, 1998; Todman & Dugard, 2001), (b) reported the 95% confidence intervals within the two momentum conditions (cf. Cumming, 2014), and (c) reported a conventional effect size measure, as well as a corrected effect size and a "common language effect size" (see Lakens, 2013).

To conduct reliable comparisons between momentum conditions in terms of the judged puttability, we decided to set the baseline distance to 100% and to determine the relative change in the momentum session. Subsequently, in accordance with the Monte Carlo permutation procedure, we shuffled the relative changes of all participants across the positive and negative momentum conditions 10,000 times. After each round of shuffling the average simulated difference between conditions, in percentages, was compared to the observed difference. When the probability of finding the same or more extreme difference between the positive and negative momentum conditions was low ($p < .05$), we could conclude that the observed difference was unlikely to be caused by chance. With regard to size judgment, we followed a comparable procedure. The changes in judged hole size were shuffled 10,000 times, and we computed the probability of finding a same or more extreme difference between momentum conditions than the one that we had observed.

Then, within each condition—positive momentum or negative momentum—we simulated 95% confidence intervals based on 10,000 resamplings of the collected data (cf. Den Hartigh et al., 2016). To determine the meaningfulness of any significant results, we provided an estimate of the effect size by calculating Cohen's *d* (computed as the observed result divided by the pooled *SD*), where a *d*-value of .2 or lower is traditionally considered as small, .5 as medium, and .8 or higher as large (Cohen, 1988). In line with the guidelines by Lakens (2013), we added Hedges's *g* (Hedges and Olkin, 1985) and a common language effect size (McGraw & Wong, 1992). Hedges's *g* is a correction for Cohen's *d*, and is considered an unbiased effect size estimate (Cumming, 2012). The common language effect size indicates the chance that for a randomly selected pair of individuals from the two conditions, the score (e.g., percentage) of a person from the positive momentum condition is higher than the score of a person from the negative momentum condition.

## 3. Results

### *3.1 Puttability affordance judgment*

The 20 participants that we analyzed were about equally distributed over the momentum groups in terms of gender and sports (positive momentum condition: Six males, four females, including five golf players, three hockey players, and two tennis players; negative momentum condition: Seven males, three females, including three golf players, five hockey players, and two tennis players). Eight out of ten participants in the positive momentum condition placed the ball further from the hole relative to the baseline session, and eight out of ten participants in the negative momentum condition placed the ball closer to the hole. Figure 2 displays the relative distances in the positive and negative momentum conditions. Taking a closer look at these distances and their 95% confidence intervals based on a resampling procedure, the average distance relative to the baseline corresponded to 113% in the positive momentum condition (95% CI = 97% to 130%), and to 83% in the negative momentum condition (95% CI = 69% to 95%). The Monte Carlo permutation test revealed that the relative difference of 30% between the positive and negative momentum conditions was statistically significant ($p = .006$) with a large Cohen's $d$ of 1.23. The corrected effect size, provided by Hedges's $g$, also revealed a high value of 1.18. According to the calculation of the common language effect size, there is an 81% chance that for a randomly selected pair of individuals the score of the individual in the positive momentum condition is higher than the score of the individual in the negative momentum condition.

### *3.2 Size judgment*

One participant in the positive momentum condition picked the smallest circle in the baseline session and in the posttest, and later justified his choices by saying that he tends to imagine the smallest possible hole to improve his putting accuracy. Because this participant did not pick a hole size based on any perceptual judgment, he was excluded for this analysis.

Of the remaining participants in the positive momentum condition, four out of nine picked a bigger circle after the momentum manipulation than in the baseline session, whereas five participants picked the same circle-size. In the negative momentum condition, two participants picked a smaller circle, two picked the same circle, and six picked a bigger circle. As could be expected from this inconsistent pattern, the change in hole size in the positive momentum condition (*M* = 1.11, *SD* = 1.45) did not significantly differ from the change in the negative momentum condition (*M* = 1.40, *SD* = 1.90; *p* = .41).

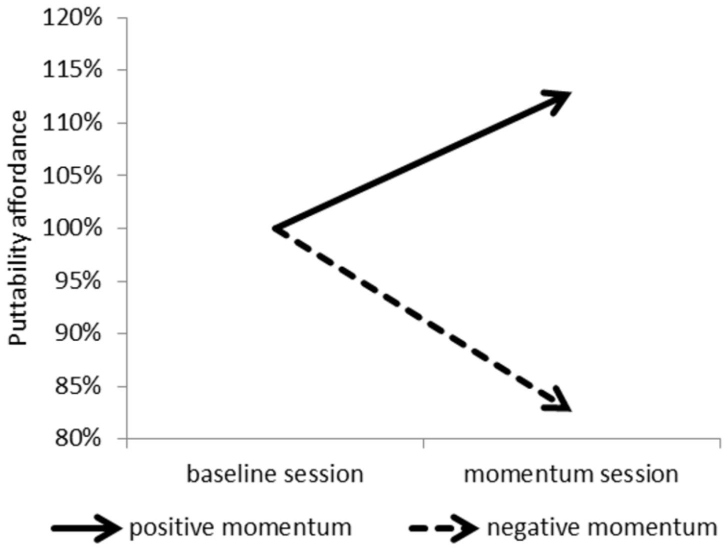


*Figure 2.* Visual representation of the maximum puttable distance after the momentum manipulation in the positive and negative momentum sessions, relative to the baseline session (set to 100%).

**4. Discussion**

The current study aimed to investigate whether athletes' judged affordances and judged features of the environment are related to PM. Therefore, we conducted an experiment in which participants' judgments of puttability and hole-size before and after a positive or negative momentum manipulation were compared. In line with our first hypothesis, we found that participants indicated the maximum puttable distance as relatively further from the hole in a positive momentum condition than in a negative momentum condition. This result supports our idea that athletes' affordances change during positive and negative PM in a sports match. An interesting observation was that the simulated 95% CI of the negative momentum condition had an upper boundary below 100%, whereas the 100% just fell within the 95% CI of the positive momentum condition. This suggests that the effects of moving away from the victory are stronger than the effects of moving toward the victory, which is in line with previous research examining psychological and behavioral changes during positive and negative momentum scenarios. More specifically, recent PM studies consistently found that negative momentum scenarios have a bigger impact on athletes' psychological and behavioral states than positive momentum scenarios (Briki et al., 2013; Briki, Den Hartigh, Hauw et al., 2012; Den Hartigh & Gernigon, in press; Den Hartigh, Gernigon et al., 2014; Gernigon et al., 2010).

The hole size judgments were not significantly affected by our momentum manipulation. Contrary to our second hypothesis, participants did not judge the hole to be relatively bigger during positive PM than during negative PM. This result was unanticipated, because Witt and colleagues have repeatedly demonstrated that people perceive the world in terms their ability to act in it (e.g., Witt, 2011; Witt et al., 2008; Witt & Riley, 2014), and athletes' momentary abilities are assumed to vary with PM (e.g., Iso-Ahola & Dotson, 2016; Jackson & Mosurski, 1997). Thus, it seems that PM is not related to the perception of spatial features in the environment, whereas it can be linked to the perceived relation between spatial features *scaled to* the athlete's abilities. These contradictory findings may cast doubt on the position that action-specific perception and affordances are directly related (Witt & Riley, 2014). A recent study in a soccer context, in which no experimental manipulation was applied, also showed an overall low correlation between players' "kickability" affordance from a given distance from the goal, and their judgment of the distance from the goal (Paterson, Van der Kamp, Bressan, & Savelsbergh, 2016). However, our outcomes may not allow drawing firm conclusions about the link between affordances and action-specific perception, as our experiment was not designed to explicitly test this link, and there may be alternative explanations for the absence of an action-specific perception effect in our study. For instance, we repeatedly occluded the vision of participants during the golf-competition. According to Cañal-Bruland, Zhu, Van Der Kamp, and Masters (2011), action-specific perception effects only occur when focusing visual attention on the target while performing one's action (but see Witt, Sugovic, & Dodd, 2016, for recent empirical evidence that attention does not influence perceptual judgments).

### *4.1 Theoretical implications*

Although our study was a first test and future replications across different contexts are encouraged, showing a link between PM and affordance dynamics may have interesting theoretical implications. Changes in PM could be incorporated in a formal theory of athletes' changing affordances on the sports field. Given our results, a concrete possibility is that a PM experience changes (perceived) action boundaries, or critical points, at which an action can be successfully sustained (cf. Bootsma et al., 1992; Warren, 1984). The link between PM and affordance dynamics may also extend the theoretical idea that PM processes can be observed at different time scales (e.g., Den Hartigh et al., 2016; Hubbard, 2015, 2017). Den Hartigh et al. (2016) found that, when moving away from the victory in an ergometer rowing contest, athletes' exerted efforts, perceptions of momentum, and self-efficacy decreased particularly rapidly in case the they had developed negative PM across multiple races (i.e., after successive losses in the ergometer rowing tournament). The idea that affordances are influenced by PM suggests that PM dynamics also embed the short-term (real-time) perception-action dynamics (see also Hubbard, 2015, 2017, for another perspective on the idea that momentum-like effects can be observed across different modalities and time scales).

When considering our results from a more traditional psychological perspective, one could argue that the momentum manipulation potentially had an effect on participants' self-efficacy in terms of their belief in their ability to make a putt from a particular distance (Bandura, 1997). Although we cannot rule this out, we are not in a position to assess this proposition. In our study, we aimed to make the first step in linking PM to affordances, and therefore proceeded from the research traditions of PM and affordances. A study on self-efficacy in golf would likely have included asking participants to fill out a self-efficacy questionnaire about their belief in their ability to successfully make a putt from different distances. This would have provided a typical self-efficacy measure based on a kind of cognitive estimation (cf. Bandura, 2006; Feltz, Short, & Sullivan, 2008). In our study, however, we asked participants to judge, within the performance environment, the maximum puttable distance by dropping the ball on the ground at that distance. This is a measure of the participant's judged possibility for action, that is, of the participant's judged affordance (cf., Oudejans et al., 1996; Pepping & Li, 2000; Postma et al., in press; Warren, 1984; Weast et al., 2011).

*4.2 Future avenues*

This study is the first to reveal a link between PM and affordances. When perceiving that one's goal, such as the victory, gets within reach (positive PM) or out of reach (negative PM), what is perceived as literally reachable in the performance environment also seems to change. An open question remains whether PM impacts the affordances per se, or (only) their judgments. In other words, does PM also change our actual possibilities for action? Another interesting question is whether changes in affordances may also play a (important) role in the generation of a PM experience? According to Iso-Ahola and Dotson (2016), for instance, the perception of oneself as a performer relative to the subjective perception of the opponent are important ingredients for the development of PM. Extending this idea to the connection between affordances and PM, affordances are the relational properties between environmental features and the actor's abilities, which are measurable entities in terms of action boundaries that can be asked to judge (i.e., which actions are possible and which are not). Possibly, the changes in (judged) affordances are key in generating the phenomenological experience of PM, and vice versa. In order to test these speculations, future research should attempt to (a) manipulate PM and examine the effects on actualized affordances, and (b) manipulate affordances and examine the effects on actors' PM experience. Together, such studies may further advance theorizing about the theoretical connection between PM and affordances.

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