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Choking under pressure in front of a supportive audience: Evidence from professional biathlon

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ABSTRACT

Performing in front of a supportive audience increases motivation. However, it also creates psychological pressure, which may impair performance, especially in precision tasks. In this paper, we exploit a unique setting in which professionals compete in a real-life contest with large monetary rewards in order to assess how they perform in front of a supportive audience. Using the task of shooting in the sprint competitions of professional biathlon events over a period of 16 years, we find that for both genders, biathletes from the top quartile of the ability distribution miss significantly more shots when competing in their home country compared to competing abroad. Our results are in line with the hypothesis that high expectations to perform well in front of a friendly audience prompt individuals to choke when performing skill-based tasks.

1. Introduction

There are many professions in which individuals perform tasks in front of an audience. Examples include lecturers at universities, presenters in marketing companies, researchers at conferences, politicians during public speeches, athletes in sports competitions, etc. Successful execution of these tasks may result in the receipt of large monetary rewards. For example, a convincing presentation in a job interview may have a very influential impact on the person's career. In this paper, we ask two simple questions. First, does performing in front of a supportive crowd enhance or impair performance? Second, do individuals with greater or less ability react differently in such situations?

It is intuitive that performing in front of a supportive crowd increases motivation, since succeeding in front of familiar people who expect (and desire) a successful performance might be more satisfying. However, it can also be much more disappointing when the people closest to you witness your failure. Therefore, from an economic perspective, the difference between the utility in the case of a strong performance and that of a poor performance is much more pronounced when performing in front of a supportive crowd than when performing in front of a neutral one. Incentives to perform well are therefore greater when in front of a supportive group. According to standard economic assumptions this increased return

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is supposed to enhance performance (Stiglitz, 1976; Lazear and Rosen, 1981; Rosen, 1986; O'Reilly et al., 1988; DeVaro, 2006, among many others). Moreover, with regard to high ability individuals, we would expect an even more pronounced enhancement when the stakes are larger (Ehrenberg and Bognanno, 1990; Lazear, 2000; González-Díaz et al., 2012; Jetter and Walker, 2015).

In most cases, these fundamental relationships hold true. Indeed, for many decades economists assumed that performance depended neither on the social context of the task environment nor on the psychological state of the performers. However, psychological research has shown that increased motivation beyond an optimal level may harm performance. This phenomenon was described by Baumeister (1984) and is known as "choking under pressure". In the same spirit, greater incentives may lead to higher levels of arousal. According to the Yerkes-Dodson law, the relationship between performance and arousal resembles an inverted U shape, meaning that performance is optimal at moderate levels of arousal and declines with over-arousal (Yerkes and Dodson, 1908). In addition, psychologists have recognized the different effects that audiences have on performance. For example, Zajonc (1965) hypothesized that the presence of others improves performance in a simple task, but impairs it in a complex task. In a later study, Baumeister et al. (1985) showed that high audience expectations created additional psychological pressure that harmed the performance of students when solving anagrams. In another experimental study that involved audiences and students, Butler and Baumeister (1998) demonstrated that participants performed worse in front of a supportive audience in skill-based math and video game tasks. Another possible explanation for the negative relationship between a supportive audience and performance in skill-based tasks could be overcautiousness, a phenomenon caused by over ambition. In other words, when people consciously monitor skill-based processes that are best executed as automated actions, the result is often a poor performance. Beilock and Carr (2001) exemplified this pattern when studying the performance of golf players. They found that a complex sensorimotor task is best performed when executed as an automated action. Overthinking or monitoring each step is likely to end with choking.

In recent years there has been greater recognition among economists of the existence of choking that stems from abnormal levels of incentives. For example, Ariely et al. (2009) used experimental settings to show that large monetary rewards can actually impair performance. In another experimental study, Ariely (2010) demonstrated that large bonuses enhance performance in a simple mechanical task, but impair it in a skill-based task. Non-experimental papers on choking mainly use data from sports competitions. For instance, Paserman (2010) as well as Cohen-Zada et al. (2017) showed that professional tennis players choke more in the most important junctures of the match. Hickman and Metz (2015) found that higher stakes in professional golf increase the likelihood of missing a shot on the final hole. Cao et al. (2011) as well as Toma (2017) presented evidence on choking under pressure in free throw shots of very close games in professional basketball.[1]

Despite this growing interest in the choking phenomenon among economists, the economic literature on the relationship between the audience and absolute performance in real tournament settings is very scarce. The main reason for this is that investigating the effect of an audience in general, let alone the effect of a supportive audience on absolute performance in real-life settings, is quite challenging. This is because in most cases reality is too complex to allow for the disentanglement of the different effects.[2] In addition, the outcome of any specific action is usually ambiguous and mostly unobserved.

There are only a handful of studies that investigate the effect of a supportive audience on performance in skill-based tasks. For example, Dohmen (2008) studied soccer penalty kicks in the German Bundesliga seasons from 1963 to 2004. He found that soccer players are more likely to choke on a penalty kick when playing in front of their home audience. Despite the intriguing result, the author noted several important caveats concerning choking. For example, a penalty kick is not a very prevalent action in a soccer match. The author reports that out of 12,488 matches observed over the span of 41 years, only 3619 penalties were awarded, meaning less than one penalty kick per every three games. Therefore, as only one player out of a team of eleven takes the penalty, self-selection into the task is very likely. In addition, this study does not control for players' time-invariant characteristics, which may play a role in stressful situations. It also does not investigate the heterogeneous effect of the home crowd on performance among players with different abilities. Finally, although the common belief is that the outcome of a penalty kick primarily depends on the kicker and not on the goalkeeper, and despite that the definition of choking in Dohmen (2008) was "[m]issing the goal without the goalkeeper's interference" (pp. 638–639), it is still theoretically possible that in a two-person interactive game, the outcome does not depend on the kicker's performance alone. In addition, Cao et al. (2011) and Toma (2017) could not replicate Dohmen's finding in basketball free throw shots. However, as in soccer, there is a similar self-selection concern in basketball, where the opposite team may strategically foul players with poor free throw accuracy. In addition, in certain situations during the last seconds of a basketball game, players from the team lagging behind may choose to miss their last shot on purpose in order to increase their chances of winning through a rebound. Therefore, the incentives to make a successful shot in the last seconds of a basketball game may even be negative. All of these caveats call for more evidence in different environments that may shed additional light on the relationship between a supportive audience and absolute performance.

[1] For additional references on the link between incentives and performance, see the comprehensive review of Gneezy, Meier and Rey-Biel (2011). In addition, see Beilock and Gray (2007) for a psychological review of choking in sports.

[2] There is a large body of literature on home advantage, which is a well-documented phenomenon in team (Moskowitz and Wertheim, 2011) and individual sports (Koning, 2011; Ferreira Julio et al., 2013; Krumer, 2017). It shows that a home contestant has a higher probability of winning (has a better relative performance). However, in interactive competitions it is not clear whether a home contestant enhances his/her performance or whether the away contestant performs worse. Moreover, a home advantage can also be attributed to referee bias rather than to contestants' performance (Garicano, Palacios-Huerta and Prendergast, 2005; Pettersson-Lidbom and Priks, 2010; Dohmen and Sauermann, 2016).

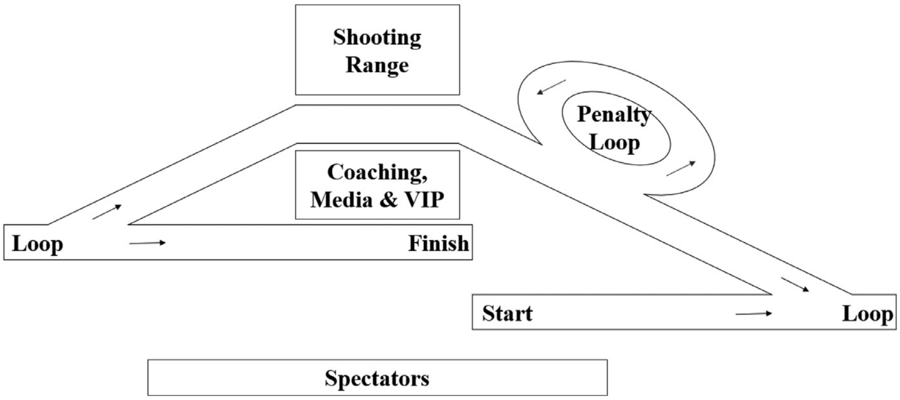

Fig. 1. Biathlon Stadium Overview (Own Depiction).

In the current study, we investigate the effect of competing in front of a supportive crowd in a completely different setting. In this setting professionals compete for large monetary rewards in real-life competitions in front of supportive and neutral crowds. More specifically, we study shooting accuracy in the sport of biathlon, which is defined by the International Biathlon Union (IBU) as "[a] sport that combines the endurance of free-technique cross-country skiing with precision small-bore rifle marksmanship" (IBU, 2016b, p.13).[3] Each missed shot implies an immediate penalty, namely, a 150 m penalty loop or the addition of one minute to the final result, which is imposed right after the task. Such penalties obviously reduce the biathlete's chances of winning the competition, because the winner is the biathlete with the best time.

Studying the effect of competing in front of a supportive crowd in biathlon is feasible because of four main features. First, unlike in other sports that involve precision tasks like soccer (penalty kicks) or basketball (free throws), every biathlete in every competition must perform the exact same non-interactive task of shooting the exact same number of times without negative incentives for a successful shot. Second, unlike in many other sports, in biathlon, the home crowd usually cheers for the home athletes, but is not hostile toward other athletes.[4] This allows us to compare the performance of athletes in front of supportive versus neutral crowds in a real-life situation. Third, the multistage nature of a biathlon season enables us to exploit within-biathlete variation. Thus, we can control for multiple sources of unobserved heterogeneity, estimate a biathlete's performance when he/she competes in front of a supportive audience (in his/her home country) and compare it to the same biathlete's performance when he/she competes in front of a neutral crowd (abroad). Finally, based on previous performance as measured by ranking points, we are able to test the heterogeneous effect of competing in one's home country among biathletes from different ability distributions. Doing so allows us to investigate whether higher ability biathletes enhance their performance at home, as predicted by economic assumptions, or, whether their performance is impaired by the burden of high audience expectations, as predicted by psychological literature.

The main analysis of this paper is based on the performance of 220 professional male and 217 professional female biathletes in all sprint competitions that took place in the World Cups, World Championships and the Olympic Games in the seasons from 2001–02 to 2016–2017. In these competitions biathletes start one after another in intervals of 30 s and shoot twice at five targets, first prone, then standing. Such interval starts allow biathletes to be alone (or at most, to be with a few other biathletes) at the shooting range. Therefore, the home crowd, primarily located near the shooting range (see Fig. 1), is able to concentrate on their preferred biathlete and is able to cheer only for him/her at the time of his/her shooting task.

Our fixed effects estimations reveal that both men and women in sprint competitions miss more shots when competing in their home country compared to competing abroad. Moreover, when we divide the data into four quartiles with regard to ability as measured by the World Cup ranking points accumulated by each biathlete before the respective competition, our cross-section analysis reveals that the only quartile in which the effect of competing in one's home country on the number of missed shots is consistently positive and significant for both genders is the quartile that represents the highest ability biathletes. The estimated effect is about 0.25 more misses on average among men and 0.28 among women. It is quite a large effect if we take into account that the average time it takes to ski a penalty loop is about 25 s, meaning that when competing at home, a biathlete loses on average 6.25 and 7 s among men and women, respectively.[5] To put this number into perspective, in the 2014 Sochi Olympic Games, the home biathlete Anton Shipulin was only 0.7 s away from a bronze

[3] To the best of our knowledge, only Balmer, Nevil and Williams (2001) have examined the home advantage in biathlon as part of a study on the Winter Olympics. The authors found no relationship between competing at home and the number of medals won.

[4] According to Sam Dolnick, who covered the 2014 Winter Olympic Games in Sochi for the *New York Times*, "[t]here's one code among biathlon fans in... countries where the biathlon is hugely popular, it's this: you do not cheer when a foreigner misses a shot." From: http://www.wbur.org/onlyagame/2014/02/22/cheering-etiquette-biathlon. Last accessed on 31/01/2018.

[5] See, for example: http://biathloncanada.ca/wp-content/uploads/2015/08/Description-of-Biathlon.pdf. Last accessed on 15/09/2017.

medal after missing one shot. Using data from less frequent individual competitions that also use an interval start, we find a similar pattern.

One possible mechanism driving the underperformance of the highest ability biathletes is Baumeister et al. (1985) contention that high audience expectations harm performance in a skill-based task. In our case, it is plausible to assume that the home audience has the greatest expectations about biathletes with the most ability, which might induce choking.[6] As evidence, the World Cup winner, Gabriela Koukalova, stated that, when competing in her home country, she was not able to concentrate at the shooting range because she felt the pressure of her nation on her shoulders. Similarly, seven-time World Cup winner, Martin Fourcade, said that it was very emotional for him to compete in his home country and also much tougher than competing abroad because of greater expectations.[7] These statements of top biathletes along with our results obtained in real-life settings as well as previous evidence from laboratory settings suggest that the most talented biathletes are more likely to choke when undertaking a precision task because of the high expectations generated by the friendly environment.

However, an alternative explanation is that the highest ability biathletes ski faster when competing at home and therefore miss more shots. The high emotional states that may appear when competing at home are likely to induce more physiological arousal, which has a positive effect on the physical subcomponents of performance and a negative effect on the cognitive aspects (Oxendine, 1970; Shaver et al., 1987; Reisenzein, 1994; Jones, 2003). However, we find that in general, faster skiing is not related to the increased number of missed shots. Moreover, biathletes from the highest ability quartile do not ski significantly faster, but still miss significantly more shots in sprint competitions. It is possible that in line with the Yerkes-Dodson law, biathletes from the top quartile achieve the optimal level of arousal when competing abroad. However, when competing in their home country, their arousal increases beyond the optimal level, which harms their performance. In addition, we find that home biathletes from other quartiles ski faster, but do not miss more shots.

Another alternative explanation is that biathletes who compete at home have many off-field distractions, such as spending more time with their families and friends prior to the competition, and therefore are less prepared to compete. In this case we would expect biathletes from all quartiles to perform significantly worse at home. However, we find this effect only among biathletes from the top quartile. Another possible off-field distraction is related to commercial obligations such as meetings with sponsors and journalists that might affect top biathletes more than the others. If so, we would have obtained the same result in mass start competitions as well, in which biathletes ski in a peloton and reach the shooting range together. However, we find no home effect in these competitions. There are several possible explanations for this outcome. The first is that the crowd cannot concentrate on one biathlete. The second is that toward the end of the competition, the race resembles a pursuit competition in which biathletes observe their relative positions, which is not the case in competitions with interval starts. Thus, the pressure and home support can be much less if the home biathletes are lagging behind. These factors probably weaken the link between the supportive crowd and shooting accuracy.

The remainder of the paper is organized as follows. Section 2 describes the biathlon setting. The data and descriptive results are detailed in Section 3. In Section 4 we present the empirical evidence and alternative explanations. Finally, in Section 5 we offer concluding remarks.

2. Description of biathlon competitions

Professional biathlon combine cross-country skiing with shooting skills. Successful biathletes must master the quick switch between a sport that is intense and physically exerting and one that requires stability and extensive control. To reflect the combination of the two contradictory disciplines, the term “competition” is preferred over the term “race.” In a nutshell, a biathlon competition can be described as follows: “[T]he athlete starts at the start line, skis one course loop ..., comes to the range and shoots, skis another loop, shoots, and so on, and then finishes by skiing to the finish line after the last bout of shooting” (IBU, 2016b, p. 484).

In total, the International Biathlon Union (IBU, 2016a) recognizes six different types of competition – sprint, pursuit, individual, mass start, relay and mixed relay. The last two are team competitions and do not count towards the individual World Cup score. Table 1 provides an overview of the three individual types of competition that we investigated. In general, depending on gender and competition type, biathletes ski up to 20 km spread over three or five loops and stop to shoot two or four times with five bullets at five targets. Shots are fired from a 50 m distance in either a prone or standing position. The targets are 45 mm and 115 mm in diameter, respectively. For each missed target a penalty minute or a 150 m penalty loop is imposed immediately after each bout. Given that the clock never stops, competitors must shoot as fast and as accurately as they can.

The sprint competition, which is the most frequent competition in biathlon, is 10 km for men and 7.5 km for women, and is skied over three loops. Competitors start one after the other in intervals of 30 s. Athletes shoot twice at five targets,

[6] Based on experience from working with American Olympic athletes, Haberl (2007) argued that being a favorite could put a considerable amount of pressure on athletes and thus impact performance in a rather negative way. He mentioned that the Olympic Gold Medalist in freestyle skiing, Nikki Stone, described the role of being the favorite as “nerve-racking.” In another study, Jordet (2009) showed that teams with high status choked under pressure during penalty shoot outs in major international soccer tournaments.

[7] From: https://www.youtube.com/watch?v=U8pKLbEmbeE and https://www.youtube.com/watch?v=fA95N95KGh8. Last accessed on 06/03/2018.

Table 1
Types of Competitions.

Type of Competition and Course Length	Standard Start Types and Intervals	Ski Loops	Shooting Bouts (5 Shots per Bout)	Shot Penalty
Sprint ♂: 10 km, ♀: 7.5 km	Single 30 sec	3	Prone, Standing	150 m
Individual ♂: 20 km, ♀: 15 km	Single 30 sec	5	Prone, Standing, Prone, Standing	1 min
Mass Start ♂: 15 km, ♀: 12.5 km	Simultaneous	5	Prone, Prone, Standing, Standing	150 m

first prone, then standing. A 150 m penalty loop must be skied for each missed shot. The final ski time is the time elapsed between start and finish. The winner is the biathlete with the best time.

In the individual competition, the biathletes start individually in intervals of 30 s, over a five-loop course of 20 km for men and 15 km for women. Athletes shoot four times at five targets in the order: prone, standing, prone, standing. Unlike other types of competitions, a penalty minute is added to the final ski time for each missed target. The final ski time is defined as the time elapsed between start and finish plus any penalty minutes imposed.

Finally, the mass start competition is limited to the top 30 competitors, who are selected based on their performance in the ongoing World Cup season, their performance in other competitions of the current event and the national franchise quotas. All competitors start simultaneously and ski five loops of a total of 15 km for men and 12.5 km for women. Trying to avoid the 150 m penalty loop, they shoot four times at five targets in the order: prone, prone, standing, standing. The first competitor to cross the finish line wins.[8]

The most prestigious events in professional biathlon are The World Cup, the World Championships and the Winter Olympic Games. The World Cup is an annual circuit of approximately 10 events in various configurations for men and women that usually take place from the end of November or the beginning of December to March. During each World Cup stage there are several different competitions. In these events, competitors can score up to 60 World Cup points (WC points) in each competition based on their performance.[9] At the end of each season, the highest (monetary and non-monetary) honors go the man and woman who placed first in the World Cup total score. This ranking is compiled based on the sum of points earned in the individual, sprint, pursuit and mass start competitions minus the two lowest scores.[10] Additional World Cup trophies are awarded to the most successful athletes based on their cumulative scores in each type of competition (IBU, 2016a).[11] The World Championship is also an annual event that counts towards the World Cup season, except in the years of Winter Olympic Games. The Winter Olympic Games also counted towards the World Cup season up to and including the 2010 Winter Olympics in Vancouver (IBU, 2008; 2016a; 2016b).

3. Data and variables

3.1. Data

The data on the seasons from 2001–02 to 2016–17 were downloaded from the official IBU website (http://biathlonresults.com/) and are based on the IBU rules.[12] The 16 seasons include 144 World Cup events, 12 World Championships and 4 Winter Olympic Games (Salt Lake City, Torino, Vancouver and Sochi). We selected this period primarily due to the accessibility and consistency of the data. Our main interest is in the sprint competition, because it is the most frequent one. In total, 155 sprint competitions out of 160 possible events in our dataset (96.9%) took place for each gender. Germany hosted a sprint competition in each of the 16 years in our data. Other frequent host countries include Austria, Sweden and Norway with 15 home sprint events each, Russia and Slovenia with 12, and Finland with 11.

The other types of competitions are significantly less frequent than the sprint competitions. For example, the individual competitions usually take place only three times per year, such that in total there are only 54 out of 160 events in our dataset (33.7%). This infrequency means that fewer countries receive the right to host these competitions. The most frequent host countries include Sweden with 12 home events, Italy with 8, and Germany with 5. Finally, Norway, Slovenia, Austria and Russia hosted an individual competition only 4 times in the 16 seasons. Mass start competitions account for 74 out of 160 events in our dataset (46.3%). The most frequent host countries include Germany with 15 home events, Norway with 12, Russia with 9 and Slovenia with 7.

We disregard the pursuit competitions, because the start time is based on the number of seconds a competitor lagged behind the winner of a sprint competition. Such ahead-behind asymmetry might jeopardize our identification strategy.

8 Pursuit competition is another competition that is not included in our analysis for the reasons presented in the following section.

9 Up to and including season 2007/08, competitors could score up to 50 WC points per competition.

10 Up to and including season 2009/10, the lowest three scores were subtracted. In addition, no scores were subtracted in season 2010/11.

11 Up to and including season 2009/10, the lowest score from the respective competition was subtracted.

12 In other words, the data reflect the ex-post disqualification of athletes due to the infringement of IBU anti-doping rules.

The data set consists of 16,177 male and 14,360 female entries in sprint competitions, 5902 male and 5244 female entries in individual competitions, and 2220 male and 2219 female entries in mass starts. Unfortunately, not all entries meet the requirements for this analysis. First, we removed invalid entries due to a biathlete not starting, not finishing, or being disqualified. Second, in accordance with Balmer et al. (2003) and Ferreira Julio et al. (2013), we excluded those athletes who never competed both at home and away to ensure comparability.[13] Therefore, in sprint competitions we analyzed the performance of 220 male and 217 female biathletes that are composed of 8262 male (832 at home) and 6540 female (736 at home) entries in different competitions. In individual competitions there are 208 male and 204 female biathletes that are composed of 2802 male (244 at home) and 2259 female (224 at home) entries in different competitions. The corresponding numbers for mass starts are 122 male and 123 female biathletes that are composed of 1793 male (221 at home) and 1403 female (211 at home) entries in different competitions.

3.2. Variables and descriptive statistics

To estimate the possible effect of competing in front of a supportive crowd on shooting accuracy we used the number of missed shots as the outcome variable. Table 2 shows that on average, for both men and women and for all types of competitions, the total number of missed shots is larger when competing at home. In addition, it would also be interesting to test the effect of competing in front of a supportive crowd on each single shot. However, unfortunately, shot-by-shot data are not available. Nevertheless, we also have information on additional performance-related measures of each biathlete such as the number of missed shots in the first bout of shooting, skiing time before this bout, final ranking and ranking points obtained in a competition.[14] Based on the accumulated seasonal points we calculated the biathletes' standardized ranking points prior to the respective competition.[15] We can see that in sprint competitions, on average, biathletes who compete in their home country have a better previous performance as represented by the larger number of standardized ranking points. However, this is not the case for the individual competition, where home biathletes have, on average, a smaller standardized number of points prior to competition.

4. Empirical evidence

4.1. Fixed effects estimations

4.1.1. Shooting performance

We estimated the impact of competing in one's home country on the number of missed shots in a professional biathlon competition. Obviously, a naïve approach of correlating a dummy variable of competing at home with the performance measure will yield biased and inconsistent estimates, because an individual's unobserved ability is likely to affect his/her shooting accuracy. This individual ability may also vary over time, differing over the years due to different preparations between seasons, for example. Hence, we need to take the different sources of unobserved heterogeneity into account.

Our panel data follows the same athletes over time, which allows us to use a fixed effects model that controls for all time-invariant differences between the individuals.[16] Therefore, we can use biathlete-season fixed effects. This means that our most general specification allows us to test the effect of competing at home by exploiting the variability of the home status across different events of the same season for a given biathlete.

Using a fixed effects model, the most basic specification takes the following form:

$$MissedShots_{itr} = a_1 \cdot Home_{itr} + a_2 \cdot X_{itr} + \mu_{it} + \delta_r + \varepsilon_{itr} \quad (1)$$

where $MissedShots_{itr}$ is the number of missed shots of biathlete i in season t and competition r. $Home_{itr}$ is a dummy variable that gets the value of one if a biathlete competes at home and zero otherwise, and X_{itr} is our set of basic controls that includes the starting number of biathletes in a competition and its squared term. We use these variables because starting numbers are not determined in a fully random way. Better athletes according to the World Cup ranking points may choose in which range of starting numbers they prefer to start. This preference usually depends on weather forecasts during the competition. Finally, μ_{it} is a biathlete's per season fixed effects, and δ_r is the specific competition's fixed effects, which

[13] In general, the biathletes we removed represent countries where biathlon is not very popular and these biathletes achieved significantly fewer ranking points. For example, in sprint competitions, these biathletes achieved on average 2.9 points among men and 5.3 points among women, compared to the biathletes who competed at home at least once with 11.4 points among men and 11.7 points among women. A similar pattern is evident in individual competitions with 3.1 and 5.2 points among men and women, respectively, compared to the biathletes who competed at home at least once with 10.5 and 10.6 points among men and women, respectively. In mass starts, biathletes without experience in competing at home achieved on average 20.2 points among men and 21 points among women, compared to the biathletes who competed at home at least once with 24.3 points and 24.9 points among men and women respectively.

[14] Note that in sprint competitions, there are 60 observations among men with missing data on skiing time, 58 of which are from the competition that took place in Russia in 2006-07 season. In addition, there are 3 missing observations among women.

[15] This variable is defined as $\frac{\text{cumulative WC Points prior comp. r of biathlete i}-\text{avg. cumulative WC Points prior comp. r of all biatlethes}}{\text{std. dev. of cumulative WC Points prior comp. r of all biathletes}}$. Since before the first competition of the season all biathletes had zero points, we used the final table of the previous season as a basis to calculate the standardized ranking points of biathletes prior to the first competition of the season.

[16] See Genakos and Pagliero (2012) and Genakos, Pagliero and Garbi (2015) for a discussion about fixed effects estimations in multi-stage sports competitions.

Table 2
Descriptive statistics.

	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
	Not home country				Home country			
Panel A: Sprint Competitions								
Variable Name	*Men's competitions (220 biathletes)*							
Total number of missed shots	2.050	1.438	0	9	2.120	1.455	0	8
Number of missed shots at the first bout of shooting	0.874	0.953	0	5	0.899	0.927	0	5
Number of missed shots at the second bout of shooting	1.177	1.024	0	5	1.221	1.041	0	5
Course time before the first bout of shooting (seconds)	465.8	44.4	295.2	703.0	466.9	43.2	303.9	660.8
Ln (ranking)	3.328	1.014	0	4.860	3.260	1.000	0	4.727
Standardized ranking points prior to competition	0.357	1.132	-0.990	4.870	0.406	1.175	-0.990	5.350
Number of observations	7430				832			
	Women's competitions (217 biathletes)							
Total number of missed shots	2.023	1.458	0	9	2.136	1.472	0	7
Number of missed shots at the first bout of shooting	0.836	0.937	0	5	0.889	0.947	0	5
Number of missed shots at the second bout of shooting	1.187	1.026	0	5	1.247	1.054	0	5
Course time before the first bout of shooting (seconds)	411.1	40.7	312.8	860.3	413.4	36.8	338.0	520.3
Ln (ranking)	3.286	1.008	0	4.779	3.262	1.033	0	4.644
Standardized ranking points prior to competition	0.286	1.143	-1.180	4.610	0.345	1.206	-1.180	4.280
Number of observations	5804				736			
Panel B: Individual Competitions								
Variable Name	*Men's competitions (208 biathletes)*							
Total number of missed shots	3.562	2.047	0	13	3.762	1.959	0	9
Number of missed shots at the first bout of shooting	0.776	0.901	0	5	0.926	0.900	0	4
Course time before the first bout of shooting (seconds)	576.8	46.7	476.4	759.7	579.8	46.2	476.3	757.5
Ln (ranking)	3.340	1.025	0	4.812	3.503	0.834	0.693	4.700
Standardized ranking points prior to competition	0.412	1.171	-0.900	4.880	0.260	1.018	-0.850	3.610
Number of observations	2558				244			
	Women's competitions (204 biathletes)							
Total number of missed shots	3.713	2.141	0	12	3.987	2.191	0	12
Number of missed shots at the first bout of shooting	0.803	0.917	0	5	0.897	0.900	0	4
Course time before the first bout of shooting (seconds)	501.3	41.9	417.3	642.3	499.2	41.5	412.9	603.4
Ln (ranking)	3.309	1.027	0	4.663	3.470	0.931	0	4.575
Standardized ranking points prior to competition	0.329	1.184	-0.870	4.550	0.113	1.050	-0.870	3.810
Number of observations	2035				224			
Panel C: Mass Start Competitions								
Variable Name	*Men's competitions (122 biathletes)*							
Total number of missed shots	3.317	1.994	0	12	3.448	1.957	0	10
Number of missed shots at the first bout of shooting	0.730	0.863	0	5	0.729	0.883	0	4
Course time before the first bout of shooting (seconds)	431.3	57.3	361.5	865.3	441.1	65.9	366.4	866.7
Ln (ranking)	2.455	0.838	0	3.401	2.393	0.873	0	3.401
Standardized ranking points prior to competition	0.088	0.999	-2.060	3.550	0.092	0.948	-2.160	2.450
Number of observations	1572				221			
	Women's competitions (123 biathletes)							
Total number of missed shots	3.350	1.957	0	11	3.422	1.907	0	9
Number of missed shots at the first bout of shooting	0.756	0.867	0	5	0.706	0.878	0	4
Course time before the first bout of shooting (seconds)	410.8	46.7	330.4	635.1	425.6	46.5	348.1	628.4
Ln (ranking)	2.407	0.858	0	3.401	2.305	0.938	0	3.401
Standardized ranking points prior to competition	0.154	1.029	-2.030	3.080	0.144	0.933	-1.660	2.710
Number of observations	1192				211			

allows us to control for all of the features of this specific competition that were common for all participants, such as the number of spectators or capacity utilization, the general climate conditions in the area of competition, and the difficulty of the track.

Given that the number of missed shots is a count variable, the natural candidates for the analysis are the Poisson regression and the negative binomial regression. However, since we use a fixed-effects estimation with a non-linear model, the only choice that does not suffer from the well-known incidental parameters problem is the Poisson model (Greene, 2004). Therefore, using a negative binomial regression would lead to biased and inconsistent estimates. Nevertheless, the possible problem with a Poisson model is the existence of overdispersion, a case when the conditional variance is larger than the conditional mean, which may result in too low standard errors and p-values. However, the so-called Poisson Pseudo Maximum Likelihood (Poisson-PML) estimator, which uses the same first-order conditions that are derived from the Poisson

Table 3
Poisson-PML marginal effect of competing at home on the number of missed shots in sprint competitions.

	(1) Men	(2)	(3) Women	(4)
	All bouts	*First bout*	*All bouts*	*First bout*
Home	0.106**	0.058*	0.154***	0.068*
	(0.052)	(0.033)	(0.055)	(0.040)
Number of observations	8249	8141	6529	6436
Biathlete per season dummies	Yes	Yes	Yes	Yes
Competition dummies	Yes	Yes	Yes	Yes
Starting number and its squared value	Yes	Yes	Yes	Yes

Note: In columns 1 and 3, the dependent variable is the total number of missed shots of biathlete *i*, in competition *r*. In columns 2 and 4, the dependent variable is total number of missed shots of biathlete *i*, in the first bout of shooting of competition *r*. Season includes all the events within the period between November to March. Standard errors clustered at the biathlete level. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

distribution, is an adjusted estimator that does not suffer from this problem (Wooldridge, 2009).[17] Following the seminal work of Santos Silva and Tenreyro (2006), this estimator is widely applied in the gravity model that is used in the international trade literature that similar to our study might have issues of heteroscedasticity, the inflation of zeros in the outcome and the use of different fixed effects.[18,19] Finally, according to Wooldridge (2009), "[i]f we are interested in the effects of the x_j on the mean response, there is little reason to go beyond Poisson regression" (p. 600).

Yet, one possible concern would be the risk of bias from censoring, since there are observations with the maximal number of missed shots. However, in the sprint competitions there are only 14 observations (0.17% of entries) with five missed shots in the first bout of shooting among men and 17 such observations (0.26%) among women. In individual/mass start competitions the corresponding numbers are 6 (0.21%)/3 (0.17%) among men and 4 (0.18%)/1 (0.07%) among women. Finally, in all the competitions for both genders there is not even one observation with maximal number of the total missed shots. Therefore, there is no serious risk of bias from censoring.

In addition, it is important to note that in our fixed effects model we do not include the standardized ranking points prior to a competition. This is because the past performance is very likely to be a function of missed shots in previous competitions and therefore is a function of $MissedShots_{it,r-1}$, $MissedShots_{it,r-2}$,.... Thus, once we include previous performance on the right hand side of Eq. (1) and conduct a fixed effects estimation, we will have a bias because the error term includes $\varepsilon_{it,r-1}$, $\varepsilon_{it,r-2}$, ..., which is obviously correlated with the past performance of biathlete *i*. Moreover, it has been shown that the size of the bias is larger when the time horizon is rather short (Nickell, 1981; Hsiao, 2003). Thus, given that in our panel dataset in sprint competitions, we have on average only 6.1 and 5.9 observations per biathlete per year for men and women, respectively, the inclusion of a past performance variable is very questionable.

Columns 1 and 3 of Table 3 present the results from estimating Eq. (1) for the total number of missed shots in sprint competitions for men and women, respectively. The standard errors clustered on the biathlete level are in parentheses. The results show that the coefficients of $Home_{itr}$ are positive and significant at the 4.3% level for men and at the 0.5% level for women. More specifically, we find that a biathlete misses on average 0.11 (men) and 0.15 (women) shots more when competing at home than when competing abroad.[20]

As discussed previously, 0.10 misses are equivalent to on average 2.5 s in a competition, which is not a negligible amount of time in professional biathlon. In addition to the example of Anton Shipulin that was discussed in the introduction, it is worth mentioning the German biathlete, Rico Gross, who was only 0.2 s away from the Olympic medal in the 2002 Salt Lake City Olympic Games. Similar examples also exist among women, where in the 2006 Turin Olympic Games, a Swedish silver medalist, Anna Carin Olofsson-Zidek, was only 2.4 s behind the winner. Similarly, in the 2010 Vancouver Olympic Games, the Russian biathlete, Anna Frolina, missed the bronze medal by only 1.2 s.

In Columns 2 and 4 we present the results for the first bout of shooting. This is because failing to shoot well may have an effect on subsequent performance, therefore it is interesting to investigate the performance of biathletes when they have not experienced a success or failure in the shooting task. The results show that both men and women miss significantly more shots when competing at home already in the first bout of shooting.[21]

4.1.2. Skiing performance

According to Wallace et al. (2005), apart from the negative effect of a supportive audience on skill-based tasks, such an audience also has a positive effect on effort-based performance. Additionally, according to Ariely (2010), a stronger

[17] The Poisson PML is also called the Quasi Maximum Likelihood Estimator.

[18] In addition, see Santos Silva and Tenreyro (2011) who showed that the Poisson-PML estimator allows for a large fraction of zeros in the data.

[19] All of the estimations were performed via the *ppml* command in Stata. See http://personal.lse.ac.uk/tenreyro/lgw.html for additional information on the *ppml* command. Last accessed on 07/03/2019.

[20] Note that Poisson PML drops observations that are perfectly predicted.

[21] We also tested the effect of competing at home on clean shooting (zero missed shots). The coefficients of the Linear Probability Model are negative, but not significant at conventional level for sprint competitions. The results of these regressions are available upon request.

Table 4
Linear model estimates of the effect of competing at home on the course time before the first bout of shooting.

	(1) Men	*(2)*	*(3)*	*(4)* Women	*(5)*	*(6)*
	Sprint	*Individual*	*Mass start*	*Sprint*	*Individual*	*Mass start*
Home	-1.253***	-1.927*	0.055	-1.880***	-2.122**	-0.244
	(0.303)	(1.014)	(0.423)	(0.389)	(0.955)	(0.611)
Number of obs.	8202	2802	1793	6537	2259	1403
Biathlete per season fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes
Starting number and its squared value	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the course time in seconds before the first bout of shooting of biathlete *i*, in competition *r*. Season includes all the events within the period between November to March. Standard errors clustered at the biathlete level are presented in brackets. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

motivation promotes performance of mechanical tasks. One explanation for this effect may be the impact of arousal on different types of performance. In a meta-analysis of the relationship between the presence of others and arousal, Mullen et al. (1997) found that audiences increase both cognitive and physical arousal through periodic social monitoring, apprehension about being evaluated and attentional conflict. Thus, competing in front of an audience can be considered a type of arousal affecting biathletes in both skiing and shooting. Moreover, as emotions can cause changes in arousal (Shaver et al., 1987; Reisenzein, 1994; Jones, 2003), competing at home is likely to result in higher levels of arousal. Various researchers have suggested that arousal affects the physical and cognitive subcomponents of performance differently (Woodman et al., 2009). Physiological arousal has been positively linked to performance in Sargent jump (Parfitt et al., 1995) and strength tasks (Perkins et al., 2001), but negatively to tasks that require fine motor control (Noteboom et al., 2001). In skiing, higher levels of arousal from competing at home can increase anaerobic power, which improves performance on simple physical tasks (Jones, 2003).

Therefore, the aim of this sub-section is to study the effect of competing in one's home country on skiing performance, which is an effort-based task. To this end we use the course time before the first bout of shooting, which is, in our opinion, the cleanest possible way. This is because the skiing time after the first shooting may be affected by shooting performance. For example, athletes who missed might be discouraged because of their poor shooting performance or might be more tired because of additional penalty loops compared to athletes who did not miss.

Column 1 and 4 of Table 4 shows that athletes ski significantly faster at home in sprint competitions. The estimated effect is between 1.25 s for men and 1.88 s for women. We find a similar result for individual competitions where men and women ski about 2 s faster in their home country compared to abroad. However, we find no such effect in mass starts. This is not surprising, because unlike sprint and individual competitions where biathletes ski mostly alone against the clock, mass start competition is a contact competition. In mass starts biathletes ski in a peloton at the beginning. Therefore, we should not expect faster home skiing in these competitions.

One possible explanation for the higher number of missed shots when competing at home is that biathletes ski faster at home, possibly increasing their heart rate and thus, harming their shooting performance. However, the evidence on the association between heart rate and shooting performance is mixed. On one hand, Kayihan et al. (2013) showed a negative correlation between heart rate and pistol shooting performance from a 10 m distance. On the other hand, Kruse et al. (1986) found no relationship between heart rate and shooting performance with a standard pistol from a 25 m distance. The authors attributed better shooting performance to fewer hand tremors. Similarly, Konttinen et al. (1998) failed to establish a relationship between heart rate patterns and shooting performance. Moreover, according to Lakie (2010), "[h]igh heart rate shooting is not a big problem in biathlon" (p. 449). Indeed, the increased heart rate in biathlon may even be an advantage, because it decreases the pulsatile input to the rifle, thereby reducing the chances of error.

In addition, according to Hoffman et al. (1992), biathletes reduce their skiing intensity as they approach the shooting range. The authors found that the intensity of exertion immediately prior to the shooting task had minimal influence on prone shooting. Similarly, Coote (2010) suggested that in addition to training of breath and heart rate control, biathletes often reduce their skiing speed as they approach the shooting task to allow their heart and breathing to slow. However, it is still possible that the home biathletes do not slow down before the shooting task, which obviously improves their skiing performance, but may harm their shooting performance.

In the following we probe more deeply into the relationship between shooting and skiing performances and competing at home. Despite the fact that the course time before the first bout of shooting is an outcome and therefore, according to Angrist and Pischke (2008) is defined as a "bad control," we nevertheless add this variable as an additional control variable in Eq. (1). As shown previously, the $Home_{itr}$ variable affects both the number of missed shots and the skiing time before the first shooting. We are, however, interested in whether the $Home_{itr}$ variable has an effect on the number of missed shots through another channel than just faster skiing. Therefore, regressing the number of missed shots on the $Home_{itr}$ variable and skiing time and finding that the $Home_{itr}$ variable is still positive and significant would suggest that competing at home has a negative effect on shooting performance not only through faster skiing.

Table 5
Poisson-PML marginal effect of competing at home and skiing performance on the number of missed shots in the first bout of shooting.

	(1)	*(2)*	(3)	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Panel A: Men	*Sprint*		*Individual*			*Mass start*		
Skiing time before bout 1	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.003)		-0.001 (0.003)	-0.002 (0.005)		-0.002 (0.005)
Home		0.060* (0.033)		0.277*** (0.080)	0.275*** (0.081)		0.045 (0.081)	0.044 (0.081)
Number of obs.	8083	8083	2400	2400	2400	1574	1574	1574
Panel B: Women	*Sprint*		*Individual*			*Mass start*		
Skiing time before bout 1	-0.002 (0.002)	-0.001 (0.002)	-0.002 (0.004)		-0.002 (0.004)	0.008*** (0.003)		0.008*** (0.003)
Home		0.065 (0.040)		0.080 (0.089)	0.076 (0.088)		-0.035 (0.092)	-0.031 (0.092)
Number of obs.	6433	6433	1910	1910	1910	1258	1258	1258
Biathlete per season dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Starting number and its squared value	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the number of missed shots of biathlete *i*, in the first bout of shooting in competition *r*. Season includes all the events within the period between November to March. Standard errors clustered at the biathlete level are presented in brackets. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

Column 1 of Table 5 shows that the coefficient of the skiing time before the first bout of shooting is almost zero and highly insignificant in explaining the number of missed shots in the first bout of shooting in sprint competitions among men and women. Column 2 presents the results of a regression where the $Home_{itr}$ variable and skiing time appear together on the right-hand side of the equation. The $Home_{itr}$ variable remains positive and significant for men. In the case of women, the $Home_{itr}$ variable is also positive and very close to significance level with p-val of 0.102. We can also see that the size of its magnitude is almost unchanged compared to results presented in Columns 2 and 4 of Table 3. The skiing time remains highly insignificant. As described previously, this result indicates that competing at home has a negative effect on shooting performance that is not related to faster skiing.

4.1.3. Robustness checks

In addition to the possible effect of arousal on performance, there is another, possibly co-existing, mechanism that might impair shooting performance at home. It is based on the explicit monitoring theory, which links a decline in performance to home crowd support through undesired cognitive processes. In other words, athletes choke in critical situations because pressure affects their attentional focus. For example, Beilock and Carr (2001) presented evidence on the explicit monitoring theory based on putting in golf, which represents a complex sensorimotor task best performed when executed as an automated action. Therefore, it is possible that individuals choke when a high-pressure situation provokes them to monitor their actions more closely instead of executing them in an automated manner. In our case, it is plausible to assume that when the audience, primarily located near the shooting range (see Fig. 1), cheers (the loudest for local favorites), the biathletes competing at home overthink instead of shoot as practiced. This situation is more likely to occur in competitions with interval starts, such as the sprint and individual competitions, and less likely to occur in mass starts. The latter is a contact competition, where all the athletes start and arrive at the shooting point together (mostly in the first bout of shooting, but also in the following ones). Therefore, the element of a peloton race, where the crowd is not concentrated on one athlete alone, as in the sprint and individual competitions, makes the link between the supportive crowd and shooting accuracy less strong.

In the current sub-section our aim is to test the individual and mass start competitions. Columns 3–5 of Table 5 present the results of individual competitions. Similar to the case of sprint competitions, the coefficient of skiing time is very close to zero and highly insignificant whether or not we include the $Home_{itr}$ variable. In addition, and again similar to the sprint competitions, the $Home_{itr}$ variable is positive and in the case of men, significant, whether or not we control for skiing time. Men miss almost 0.28 shots more when competing in their home country compared to abroad. Since in individual competitions a penalty minute is added to the final ski time for each missed shot, our results imply that the home biathletes lose on average close to 17 s after the first bout of shooting. For the case of women, we also obtain a positive coefficient of $Home_{itr}$, which is even somewhat higher than in the women's sprint competitions. However, it is not significant at conventional level. This lack of significance may arise from the small number of observations (3.4 times fewer observations than in the women's sprint) and host countries, as was described in sub-Section 3.1.

As expected, the results in the mass starts differ from those in the sprint and individual competitions. We find no significant results for the $Home_{itr}$ variable. Moreover, women who compete in their home country seem to miss slightly more shots if they ski slower. The absence of the effect of competing at home in mass starts is not surprising, because, as explained above, this is mostly a peloton race where all of the biathletes reach the first shooting range together and the crowd cannot concentrate on one biathlete, as happens in the sprint and individual competitions.

One possible mediator of choking in sprint and individual competitions may be related to a simple physiological tremor that biathletes might experience when performing in front of a supportive crowd. This tremor may be caused by the increased level of adrenaline, which is detrimental for precision tasks and may occur in stressful situations.[22] However, we cannot test these theories directly, because we do not have data on biathletes' blood pressure, the level of adrenaline in their blood or how much attention they lose when competing in their home country. One additional explanation is that it is athletes with strong abilities who choke under pressure because of the greater expectations of them. We test this hypothesis in the following sub-section.

4.2. Cross-section analysis

4.2.1. Shooting performance

It is intuitive that being a favorite implies greater expectations and puts a considerable amount of pressure on an athlete (Baumeister et al., 1985; Haberl, 2007; Jordet, 2009). Therefore, it is possible that public expectations have a different effect on the performance of biathletes from different ability distributions. For instance, higher ranked biathletes performing at home may experience more pressure than their less skilled teammates. In such a case the negative effect of competing at home will be more pronounced among athletes with more abilities. On the other hand, those with greater ability are expected to improve their performance when the stakes are higher (Rosen, 1986; Ehrenberg and Bognanno, 1990; Lazear, 2000; González-Díaz et al., 2012; Jetter and Walker, 2015). Therefore, it is possible that these higher ranked biathletes performing at home are more invigorated than their lower ranked counterparts when competing in front of a supportive audience.

To probe more deeply into the influence of performing at home among different types of biathletes, we interact the home variable with variables related to the quality of the biathletes. We used cumulative World Cup points prior to the competition of each biathlete as a proxy of his/her ability. However, one concern is that there are biathletes whose ranking points before the respective competition is zero. One might conclude that these athletes have less ability because they did not achieve any ranking points in previous competitions. Alternatively, this lack of scoring might also be a technical issue. For example, some biathletes might not have competed in the previous season. Consequently, we did not assign them ranking points in the first competition of the season. It is also possible that some biathletes did not compete in the first competitions of the season because of injury, illness or unique training schedules.[23] Since biathletes with zero ranking points before the respective competition might be a source of statistical noise, we omitted them.

Within each competition we sorted the cumulative World Cup points prior to the respective competition into four quartiles of increasing quality. The first quartile (*Q1*), in which the cumulative World Cup points prior to competition are low, corresponds to biathletes with the least ability, and the fourth quartile (*Q4*) in which the cumulative World Cup points prior to competition are high corresponds to biathletes with the greatest ability. In the new dataset of sprint competitions, *Q1* consists of 162 men and 109 women home entries. In *Q2* there are 147 men and 122 women home entries. In *Q3* there are 141 men and 145 women home entries. Finally, in *Q4* there are 172 men and 142 women home entries. As previously, the number of home entries in the individual and mass start competitions is much lower. In individual/mass start competitions, *Q1* consists of 47/58 men and 51/52 women home entries only, which is even less in *Q2,* where there are only 38/48 men and 37/56 women home entries. In *Q3* there are 50/59 men and 35/59 women home entries. Finally, in *Q4* there are 39/56 men and 30/44 women home entries only.

It is important to note that in this approach we cannot use fixed effects estimation because of the violation of the assumption of strict exogeneity, according to which the mean-differenced errors are uncorrelated to the treatment or regressors from any time period (Cameron and Trivedi, 2005). This is because past performance might move a biathlete between different quartiles. In addition, the home variable, which is our treatment, interacts with these quartiles. Therefore, past outcomes also affect the current treatment. Our most basic specification takes the following form:

$$\begin{aligned} MissedShots_{itr} = {} & a_1 \cdot Home_{itr} + a_2 \cdot X_{itr} + Q_{2itr} + Q_{3itr} + Q_{4itr} \\ & + Q_{2itr} \cdot Home_{itr} + Q_{3itr} \cdot Home_{itr} + Q_{4itr} \cdot Home_{itr} + \delta_r + \varepsilon_{itr} \end{aligned} \tag{2}$$

Columns 1 and 2 of Table 6 present the results for the sprint competitions for men (Panel A) and women (Panel B) for the total number of missed shots and the number of missed shots in the first bout of shooting, respectively. The standard errors clustered at the competition level are in parentheses. First, we can see that as the biathletes' ability increases, their

[22] For example, in the 2008 Beijing Olympic Games, the North Korean shooter Kim Jong Su won silver and bronze medals, but was disqualified after testing positive for propranolol, a drug that blocks the action of adrenaline. From: https://www.scientificamerican.com/article/olympics-shooter-doping-propranolol/. Last accessed on 07/03/2019. See also Lakie (2010) who discusses the possible inverse correlation between tremor and shooting performance in biathlon. For additional neuropsychological mechanisms of choking, see the recent review of Yu (2015).

[23] To illustrate, the 2016-17 World Cup winner Laura Dahlmeier did not compete in the first competition of the 2017-18 season because of illness. In addition, four-time Olympic Champion Darya Domracheva did not compete in the 2015-16 and the beginning of the 2016-17 seasons due to illness and pregnancy. Similarly, two-time World Champion and Olympic medallist Jakov Fak missed almost the entire 2016-17 season due to illness where he achieved no ranking points.

Table 6
Poisson-PML marginal effects of competing at home on the number of missed shots.

	(1) All bouts	*(2)* First bout	(3) All bouts	*(4)* First bout	*(5)* All bouts	*(6)* First bout
Panel A: Men	*Sprint*		*Individual*		*Mass Start*	
Home	-0.119	-0.049	0.031	0.156	0.212	0.080
	(0.102)	(0.072)	(0.233)	(0.104)	(0.246)	(0.127)
Q2	-0.186***	-0.099***	-0.008	-0.001	-0.256	-0.062
	(0.048)	(0.034)	(0.117)	(0.048)	(0.176)	(0.084)
Q3	-0.375***	-0.189***	-0.583***	-0.255***	-0.227	0.015
	(0.049)	(0.031)	(0.129)	(0.070)	(0.244)	(0.112)
Q4	-0.668***	-0.306***	-0.955***	-0.303***	-0.279	0.057
	(0.056)	(0.035)	(0.135)	(0.060)	(0.327)	(0.144)
Q2*Home	0.192	0.068	0.017	-0.213	0.243	0.061
	(0.155)	(0.108)	(0.357)	(0.160)	(0.369)	(0.171)
Q3*Home	0.184	0.033	0.301	0.085	0.114	-0.001
	(0.163)	(0.104)	(0.424)	(0.196)	(0.316)	(0.169)
Q4*Home	0.370**	0.114	0.314	0.110	-0.546	-0.261
	(0.157)	(0.104)	(0.350)	(0.180)	(0.420)	(0.197)
H_0: Home+Q2*Home	0.073	0.019	0.048	-0.057	0.455	0.141
(p-val)	(0.519)	(0.797)	(0.862)	(0.597)	(0.126)	(0.237)
H_0: Home+Q3*Home	0.065	-0.016	0.366	0.241	0.326	0.079
(p-val)	(0.602)	(0.857)	(0.247)	(0.107)	(0.138)	(0.472)
H_0: Home+Q4*Home	0.251**	0.065	0.345	0.266*	-0.334	-0.181
(p-val)	(0.031)	(0.411)	(0.199)	(0.062)	(0.301)	(0.240)
Number of obs.	6209	6209	2152	2152	1793	1793
Panel B: Women	*Sprint*		*Individual*		*Mass Start*	
Home	-0.033	0.009	-0.297	0.025	0.021	-0.011
	(0.139)	(0.082)	(0.308)	(0.117)	(0.228)	(0.118)
Q2	-0.220***	-0.067*	-0.389***	-0.098*	-0.088	-0.097
	(0.056)	(0.036)	(0.120)	(0.058)	(0.196)	(0.085)
Q3	-0.406***	-0.164***	-0.702***	-0.140*	0.007	0.122
	(0.055)	(0.037)	(0.138)	(0.076)	(0.280)	(0.126)
Q4	-0.583***	-0.239***	-1.227***	-0.233***	0.215	0.465***
	(0.063)	(0.042)	(0.119)	(0.064)	(0.386)	(0.178)
Q2*Home	0.114	-0.058	0.598	0.133	0.096	0.058
	(0.186)	(0.131)	(0.509)	(0.162)	(0.341)	(0.180)
Q3*Home	0.169	0.012	1.013**	-0.055	-0.082	-0.168
	(0.170)	(0.109)	(0.423)	(0.177)	(0.345)	(0.185)
Q4*Home	0.315	0.176	0.297	0.148	0.274	-0.164
	(0.194)	(0.115)	(0.476)	(0.184)	(0.418)	(0.197)
H_0: Home+Q2*Home	0.081	-0.049	0.301	0.158	0.117	0.047
(p-val)	(0.508)	(0.612)	(0.434)	(0.156)	(0.701)	(0.728)
H_0: Home+Q3*Home	0.136	0.021	0.716***	-0.030	-0.060	-0.179
(p-val)	(0.223)	(0.974)	(0.006)	(0.804)	(0.834)	(0.201)
H_0: Home+Q4*Home	0.282**	0.185**	0.000	0.173	0.295	-0.175
(p-val)	(0.031)	(0.016)	(0.999)	(0.192)	(0.357)	(0.248)
Number of obs.	4778	4778	1653	1653	1403	1403
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes
Star. num. and its sq. val.	Yes	Yes	Yes	Yes	Yes	Yes

Note: In columns 1, 3 and 5, the dependent variable is the total number of missed shots of biathlete *i*, in competition *r*. In columns 2, 4 and 6, the dependent variable is total number of missed shots of biathlete *i*, in the first bout of shooting of competition *r*. Standard errors clustered at the competition level are presented in brackets. P-val for different H_0 hypotheses are in brackets. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

shooting performance becomes better, as represented by the decreasing coefficient of *Qj*. This result might suggest that our ability measure performs according to expectations. Next, our aim is to investigate the effect of competing at home on the number of missed shots. To calculate this effect in *Q4,* we total the coefficients of *Home* and *Q4*Home*. We can see that for both genders, the only quartile that is significantly affected by the home variable is *Q4*, which represents the top ability athletes. The results in Column 1 show that the most capable male home biathletes miss 0.25 more shots with a significance level of 3.1%. For comparable women, that number is 0.28 more missed shots with a significance level of 3.1% as well. When studying the effect of competing at home on the number of shots missed in the first bout of shooting only, we can see that women from the highest quartile of ability miss 0.19 more shots in their home country with a significance level of 1.6%. In the case of men, the coefficient is positive, but not significant at conventional level. However, in the second bout of shooting, men from *Q4* miss close to 0.18 shots more in their home country with a significance level of 3.5% (the results of this regression are not presented, but are available upon request).

Columns 3 and 4 of Table 6 present the results for the individual competitions for the total number of missed shots and the number of missed shots in the first bout of shooting, respectively. We can see that in total, men from *Q4* miss

Table 7
Linear model estimates of competing at home on the course time before the first bout of shooting.

	(1) Men	(2)	(3)	(4) Women	(5)	(6)
	Sprint	*Individual*	*Mass Start*	*Sprint*	*Individual*	*Mass Start*
Home	-2.258**	-5.561***	-0.236	-0.605	0.345	-0.727
	(0.950)	(1.894)	(0.446)	(0.997)	(1.757)	(0.946)
Q2	-5.033***	-7.871***	-0.568	-4.489***	-6.000***	-0.646
	(0.382)	(0.681)	(0.352)	(0.686)	(0.955)	(0.653)
Q3	-7.782***	-11.793***	-0.849	-9.018***	-11.437***	-0.481
	(0.455)	(0.761)	(0.608)	(0.459)	(0.856)	(1.107)
Q4	-11.979***	-17.693***	-1.115	-15.883***	-20.369***	-1.787
	(0.472)	(0.800)	(0.732)	(0.484)	(0.894)	(1.187)
Q2*Home	-0.400	2.593	-0.216	-2.354	-2.836	1.269
	(1.103)	(2.751)	(0.937)	(1.459)	(2.687)	(1.438)
Q3*Home	0.454	4.113**	0.125	-1.185	-3.056	-0.789
	(1.258)	(1.994)	(0.759)	(1.160)	(2.992)	(1.381)
Q4*Home	1.083	8.016***	1.300	-1.578	-1.212	-0.102
	(1.367)	(2.288)	(1.081)	(1.305)	(2.758)	(1.418)
H_0: Home+Q2*Home	-2.658***	-2.968	-0.452	-3.253**	-2.490	0.561
(p-val)	(0.000)	(0.101)	(0.598)	(0.012)	(0.216)	(0.640)
H_0: Home+Q3*Home	-1.714**	-1.448	-0.112	-1.789**	-2.711	-1.496
(p-val)	(0.028)	(0.379)	(0.863)	(0.030)	(0.297)	(0.140)
H_0: Home+Q4*Home	-1.062	2.455	1.064	-2.183**	-0.866	-0.809
(p-val)	(0.205)	(0.120)	(0.274)	(0.021)	(0.696)	(0.383)
Number of obs.	6158	2152	1793	4775	1653	1403
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes
Star. num. & its sq. val.	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the course time in seconds before the first bout of shooting of biathlete *i*, in competition *r*. Standard errors clustered at the competition level are presented in brackets. P-val for different H_0 hypotheses are in brackets. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

close to 0.35 shots more in their home country. However, the result is not significant at conventional level, which is likely to be driven by the small number of observations and home countries, as described above. For the case of the first bout of shooting, men from *Q4* miss 0.27 shots more when competing in their home country compared to competing abroad. This result is significant at the 6.2% level. In the case of women, the only significant result appears for the total number of missed shots and only for biathletes from *Q3*. In fact, biathletes from this quartile miss 0.72 shots more in their home country, which implies a loss of almost 43 s. However, we have to be cautious about these results because of the very small number of home observations.

Finally, Columns 5 and 6 of Table 6 present the results for mass start competitions. As previously, we find no significant results in these competitions. One additional explanation beyond skiing in a peloton at the beginning of the competition is that toward the end of the competition, the race reminds one of a pursuit competition, where biathletes observe their relative positions, which is not the case in sprint and individual competitions. Thus, the pressure can be significantly less if the home biathletes are lagging behind. Such a lagging might also reduce the concentration of the home crowd on the specific biathlete, which probably weakens the link between a supportive crowd and shooting accuracy.

One alternative approach would be to define quartiles according to the final ranking of the previous season. In that approach, the assumption is that the abilities of biathletes are constant between seasons t and $t+1$. However, this is a very strong assumption because the ability of many biathletes may change between the seasons because of injury, illness, different preparations or age. Therefore, we prefer our current specification, which is based on more plausible assumption. Nevertheless, the findings do not change qualitatively when we use the final ranking of the previous season. The results of these estimations are available upon request.

4.2.2. Skiing performance

In Table 7 we present a similar analysis, but with the course time before the first bout as an outcome variable. We can see that for the men's sprint competitions the only quartile where biathletes do not ski significantly faster in their home country is *Q4*. Our results suggest that there is no clear pattern that relates faster skiing to poorer shooting performance. For example, male athletes from *Q2* and *Q3* ski faster at home without significantly higher numbers of missed shots, as was shown in Table 6. This result strengthens the explanation that top home biathletes from *Q4* do not miss significantly more shots in their home country because of faster skiing. In the case of women, biathletes from quartiles *Q2-Q4* ski between 1.79 and 3.25 s faster in their home country.

In the individual competition, men from *Q1*, as represented by the variable *Home*, ski 5.56 s faster in their home country. Biathletes from *Q2* ski close to three seconds faster with a significance level of 10.1%. The same pattern is observed for biathletes from *Q3*, though the effect is not significant at conventional levels. However, when we look at the performance of the most capable biathletes from *Q4*, not only do they not ski faster, but also they ski close to 2.5 s slower when competing in

Table 8
Linear model estimates of competing at home on the final Ln(ranking) in different quartiles.

	(1) Men	*(2)*	*(3)*	*(4)* Women	*(5)*	*(6)*
	Sprint	*Individual*	*Mass Start*	*Sprint*	*Individual*	*Mass Start*
Home	-0.120**	0.031	-0.088	0.068	-0.022	0.013
	(0.060)	(0.093)	(0.101)	(0.056)	(0.096)	(0.069)
Q2	-0.342***	-0.256***	-0.141**	-0.337***	-0.274***	-0.081
	(0.029)	(0.058)	(0.062)	(0.032)	(0.053)	(0.062)
Q3	-0.652***	-0.647***	-0.125	-0.744***	-0.700***	-0.131
	(0.032)	(0.064)	(0.104)	(0.035)	(0.071)	(0.103)
Q4	-1.302***	-1.195***	-0.306*	-1.404***	-1.428***	-0.323**
	(0.037)	(0.076)	(0.159)	(0.040)	(0.057)	(0.142)
Q2*Home	-0.233	-0.019	0.040	-0.075	0.131	-0.158
	(0.084)	(0.167)	(0.154)	(0.096)	(0.203)	(0.147)
Q3*Home	0.014	0.113	0.205	-0.066	0.274	-0.229
	(0.116)	(0.181)	(0.142)	(0.092)	(0.192)	(0.144)
Q4*Home	0.266**	0.303	-0.076	-0.073	-0.049	-0.008
	(0.108)	(0.181)	(0.189)	(0.122)	(0.262)	(0.173)
H_0: Home+Q2*Home	-0.352*	0.012	-0.048	-0.007	0.109	-0.145
(p-val)	(0.054)	(0.932)	(0.660)	(0.935)	(0.523)	(0.289)
H_0: Home+Q3*Home	-0.106	0.144	0.117	0.002	0.252	-0.216*
(p-val)	(0.303)	(0.314)	(0.222)	(0.985)	(0.130)	(0.077)
H_0: Home+Q4*Home	0.146	0.334**	-0.164	-0.005	-0.071	0.005
(p-val)	(0.127)	(0.037)	(0.268)	(0.964)	(0.780)	(0.975)
Number of obs.	6209	2152	1793	4778	1653	1403
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes
Star. num. & its sq. val.	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the Ln of the ranking of biathlete *i*, in competition *r*. Standard errors clustered at the competition level are presented in brackets. P-val for different H_0 hypotheses are in brackets. *, **, *** denote significance at the 10%, 5%, 1% level respectively.

their home country with a significance level of 12.0%. In the case of women, we observe non-negligible negative coefficients that are not significant at conventional levels. Again, we can attribute this outcome to the small number of observations. Finally, as expected, the coefficients in mass starts are generally lower than in the sprint and individual competitions and are also not significant. Taken together, our results suggest that choking in the shooting task occurs in competitions where the supportive crowd is concentrated on the shooting of their favorite athletes.

4.2.3. Alternative explanations

There are several alternative explanations that might drive our results. For example, it is possible that biathletes who compete at home spend more time with their families and friends prior to the competition and therefore are less prepared. In this case we would expect biathletes from all quartiles to perform significantly worse at home. However, we find this effect only among biathletes in *Q4*. Another possible explanation is that biathletes from the top quartile may have more commercial obligations such as meetings with sponsors and journalists, and these events are very likely to take place around the time of home competitions. Therefore, it is possible that off-field distractions at home events disproportionately affect the best athletes. However, the finding that there is no negative home effect on shooting performance in mass start competitions suggests that increased fatigue or more media attention are less likely to drive the results in sprint competitions. If these two factors were the main drivers, we would have obtained a similar result in mass starts as well.

In addition, it is possible that biathletes use a different strategy at home. For example, they both shoot and ski faster. Obviously, faster shooting is a more risky strategy, because it is likely to result in more missed targets. Again, if this were the explanation, we would expect the same effect among all quartiles, not just among biathletes in *Q4*. It is possible that only biathletes in *Q4* choose to use this risky strategy. However, if a biathlete chooses a different strategy in front of a supportive audience, and this strategy results in a poorer performance, then according to Beilock and Gray (2007), this biathlete chokes under pressure, because he/she performs worse than expected.

4.2.4. Overall performance

Since biathlon competitions consist of two different tasks, it is also interesting to study the effect of competing at home on the biathletes' overall performance as measured by the natural logarithm (Ln) of the final rank obtained by biathlete *i* in competition *r*. The main advantage of this measure is that the differences in the biathletes' performance are not linear; instead, they grow at an increasing rate as we move up the final ranking. Thus, for example, a difference between rank 1 and 8 corresponds to a greater difference in performance than between rank 51 and 58.

Comparing the performance of biathletes from different quartiles in sprint competitions, Column 1 of Table 8 shows that male biathletes from *Q4* obtain higher coefficients of the Ln of the final rank when competing at home. Given that a higher number indicates poorer performance, our results suggest that biathletes from *Q4* are likely to be associated with poorer overall performance when competing at home compared to their performance abroad, though the result is not significant at conventional level (p-val=0.127). Interestingly, this differential effect is significantly different between biathletes from *Q4* and biathletes from *Q1* as represented by the variable *Q4***Home*. Moreover, biathletes from *Q4* perform significantly worse in their home country compared to all the other quartiles.[24] Indeed, biathletes from *Q2* actually finish in a significantly better position when competing in their home country. Quantitatively, biathletes from *Q2* have close to a 35% better ranking in their home country compared to abroad. In contrast, biathletes from *Q4* have a 15% worse ranking when competing in their home country compared to competing abroad. We can see a similar result in men's individual competitions as presented in Column 2. We find that biathletes from *Q4* have a 33% worse ranking when competing in their home country compared to competing abroad.

Unlike in the case of men, for women there is no significant negative effect of competing at home on the Ln of their final rank. One possible explanation is that since top female biathletes from *Q4* ski faster at home, as Table 7 illustrates, their speed might compensate for the greater number of missed shots, which results in the same overall performance at home and abroad. The only significant relationship between competing at home and the Ln of the rank is found in women's mass starts among biathletes from *Q3*. One explanation for this result might be the close to significant faster time evident in Table 7. Again, our main findings are based on sprint competitions. Therefore, we must be cautious about the results in mass starts and individual competitions because of the small number of home observations.

5. Conclusion

Studying the environments that might provoke choking under pressure is an important economic task. This is because the relationship between incentives and performance is not necessarily positive over the full support, even if an individual really wants to perform well. In this paper we choose a setting where professionals perform in a friendly environment, which on one hand, motivates them to perform well, but on the other hand, might create increased pressure that provokes choking.

In general, studying the effect of competing in front of a supportive audience on absolute performance in real-life settings is not a trivial task, because nature rarely creates situations that make it possible. The natural experiment we study provides an opportunity to clearly observe the effects of performing in front of a supportive audience on high profile professionals in a real tournament setting with large monetary rewards.

Based on sprint competitions in professional biathlon over the period of 16 years and using within-biathlete variation, our findings suggest that professional biathletes, who are used to performing under immense physical strain, choke under psychological pressure when performing a shooting task in front of a supportive audience. In addition, we demonstrate that this choking pattern exists only among the most capable biathletes who perform at home. In line with the results from Baumeister et al. (1985) experimental study and statements from professional biathletes, our findings suggest that the most plausible explanation for this outcome is high expectations generated in a friendly environment.

Despite the contributions that our study makes, it also has several limitations that should be noted. First, our results come from the sport of biathlon, where the precision task of shooting follows the intensive physical effort of skiing. It is possible that the results would differ in other environments. For example, in the labor market, individuals may have to concentrate only on cognitive tasks. In addition, the results might be different with supportive audiences that are not quite as enthusiastic as crowds in sports competition or in settings where individuals perform in groups. Nevertheless, identifying the negative effect of performing a skill-based task in front of a supportive audience, especially among higher ability professionals, calls for extra attention among individuals who have to perform precise tasks in front of audiences with high expectations. Examples include conducting surgical procedures with family members present and delivering public speeches in front of a supportive crowd. Those who engage in such tasks should be mindful of the dangers of choking under pressure.

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[24] The p-val of difference between the home effect on biathletes from *Q4* and biathletes from *Q2* is 0.011. The p-val of difference between the home effect on biathletes from *Q4* and biathletes from *Q3* is 0.061.

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