Valence, form, and content of self-talk predict sport type and level of performance

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1. INTRODUCTION

Cognitive science classically suggests that language function is separated from other cognitive functions (Chomsky, 1986; Carruthers, 2002). The debate on the interdependence of language and cognition has been underway for millennia from Plato in the 5th century BC over Wilhelm von Humboldt in the 19th century to most famously Whorfian linguistics in the 20th – ranging from the claim that language is merely a medium for communicating underlying thoughts between cognitive agents (Fodor, 1975), through it being a social tool for keeping track of other people's mental states (Dunbar, 2003; Tylén et al., 2010), through language being a *lingua franca* between a number of specialized, quasi-modular central systems (Carruthers, 2002), to thoughts being fundamentally linguistic (Carruthers, 1996). In recent decades, many empirical studies have documented how language is closely intertwined with everything we do and modulates most aspects of behavior and cognition, including eye movements (Tanenhaus et al., 1995; Wallentin et al., 2011), perception of color (Maier & Abdel Rahman, 2018; Regier, Kay, & Khetarpal, 2007; Roberson et al., 2005; Winawer et al., 2007), perception of space (Levinson, 2003; Wallentin et al., 2008), respiration (MacLarnon & Hewitt, 1999), posture (Yardley et al., 1999), conditioning (Phelps, et al., 2001), imagery (Stroustrup & Wallentin, 2018; Wallentin, Rocca, & Stroustrup, 2019) and sleep (Petit et al., 2007). Adding to this, it is increasingly being recognized that whenever we are not engaged in overt linguistic exchange, our heads fill with inner speech and dialogue (Alderson-Day & Fernyhough, 2015). Humans spend as much as a quarter of our waking hours talking to ourselves (Heavey & Hurlburt, 2008). Self-talk is therefore gaining prominence as a topic of interest in cognitive science (e.g., Winsler, 2009; Hurlburt and Heavey, 2015; Morin, Uttl, & Hamper, 2011; Carruthers, 2018; Gauker, 2018; Lœvenbruck et al., 2018).

Self-talk already plays a very prominent role in sport psychology and is endorsed by both athletes and coaches as a fruitful tool for building confidence, sustaining motivation, focusing, and improving technique (Shannon, Gentner, Patel, & Muccio, 2012; Thelwell, Weston, Greenlees, & Hutchings, 2008; Vargas-Tonsing, Myers, & Feltz, 2004; Galanis, Hatzigeorgiadis, Zourbanos, & Theodorakis, 2016). It is important to study self-talk – particularly in the context of endurance and motor control, but also elsewhere – because 1) There is mounting evidence that people report to be talking to themselves (e.g. Hurlburt, Heavey, & Kelsey, 2013; Van Raalte et al., 2015; Gammage, Hardy, & Hall, 2001), and 2) Evidence is accumulating that talking to yourself positively affects performance in sport contexts (Tod, Hardy, & Oliver, 2011; Hatzigeorgiadis et al., 2011; Van Raalte, Vincent, & Brewer, 2016). In the present context, we use 'self-talk' to refer to covert verbalizations addressed to the self, although we recognize that a theoretically important distinction between covert and overt self-talk has not traditionally been made in the sport psychology literature. We were interested in internal self-talk as this is most compatible with existing research from general psychology on inner speech. Self-talk differs from other inner speech in that it is hypothesized to serve a specific function and to be somewhat discursive or dialogic (Van Raalte et al., 2016). Following Latinjak et al. (2014), self-talk may be usefully divided into *strategic* self-talk often imposed by coaches and interventions and *organic* self-talk which is either unintentional and unbidden (spontaneous self-talk) or task-relevant and proactively used by the athlete (goal-oriented self-talk). The present study focuses on organic self-talk of both spontaneous and goal-oriented varieties.

1.1. THEORETICAL MODELS OF SELF-TALK IN SPORT

In recent decades, the role of inner speech in cognition has received more and more attention in cognitive psychology with the empirical work mostly growing out of Vygotsky's self-regulation theory (e.g. Vygotsky, 1986). According to the Vygotskian perspective, inner speech is the endpoint of a trajectory moving from instructions from others (parents, caregivers) over overt self-instruction (private speech) to covert self-instruction during development. The function of inner speech in this context is enhanced planning and self-control with the child gradually taking over more strategic responsibility for her own cognition and behavior. Many studies have found that inner speech also plays a role in adult cognition, facilitating a range of cognitive functions such as problem-solving, cognitive flexibility, future planning, and impulse control (Baldo et al. 2005; Emerson & Miyake, 2003; Lidstone, Meins, & Fernyhough, 2010; Tullett & Inzlicht, 2010). All of these cognitive skills are needed to perform well in sports (see parts IV 'Motivation and Emotion' and V 'Cognition' on pp. 313-449 in Handbook of Sports Psychology, 2016), especially in situations that are challenging in terms of technique or duration (Theodorakis et al., 2000; McCormick & Hatzigeorgiadis, 2019). Tod, Hardy, and Oliver (2011) preface their systematic review on self-talk in sport by discussing evidence from the literature indicating that novice athletes may engage more in and benefit more from self-talk than more experienced athletes (compare young children and adults' self-directed, self-regulatory speech). Similarly, Hatzigeorgiadis et al. (2011) found that self-talk was more effective for novel tasks than familiar tasks, again supporting the idea that the inner voice is used for self-regulation in challenging situations. Recently, sport-specific theoretical models of self-talk have been proposed in response to the increase in empirical investigations – the theoretical debate has taken place in particular between the goal-oriented versus spontaneous self-talk framework first proposed by Latinjak, Zourbanos, Lopez-Ross, and Hatzigeorgiadis (2014) and a model based on System 1 and System 2 framework as well as a discursive perspective on inner speech (proposed by Van Raalte et al., 2016).

Latinjak et al. (2014) argued that self-talk may be usefully conceptualized in a dichotomy of goal-directed and undirected thought processes, thus modifying an original framework from cognitive neuroscience by Christoff (2012) – here, goal-directed thoughts usually occur in contexts requiring reasoning, problem-solving, and decision-making while undirected thoughts encompass thoughts or self-talk statements that come to mind effortlessly and automatically and are not necessarily related to the task or context at hand. Goal-directed thought/self-talk is deliberately put to use when solving a task, akin to when children talk to themselves out loud to direct attention and control action. It is used to represent the current model of the self and the desired model of the self and prompts actions to convert the current model to the desired model (Unterrainer & Owen, 2006). Christoff's original framework is motivated by the fact that goal-directed thinking has been disproportionately emphasized in cognitive neuroscience, often at the expense of undirected thinking which is difficult to elicit in experimental settings. Instead, she argues that we should expand our focus to include undirected thinking which has traditionally been conceptualized as a kind of drift without a function. Latinjak and colleagues adapt this framework to sport psychology research and argue that we should also investigate self-talk as either goal-directed or undirected. While Latinjak et al.'s adapted framework has been influential and many studies have adopted it, it has also received criticism (see especially Van Raalte, Vincent, Dickens, & Brewer, 2019), mainly for being too focused on theoretical taxonomy and neglecting to address the validity issues surrounding questionnaire-based approaches. These critics also point out that the framework does not make immediately testable predictions.

Although Van Raalte and colleagues have criticized Latinjak et al.'s framework, their own is in fact similar in many ways. Van Raalte et al. (2016)'s model aims to take into account the discursive nature of self-talk in light of dual-process theories (Evans & Over, 1996; Sloman, 1996; Kahneman, 2011; Stanovich & West, 2000). This model is composed of two perspectives: A) self-talk is discursive in nature, can occur internally or externally, has a function, is 'syntactically recognisable', and B) self-talk can be divided according to dual-process theories where one system is fast, intuitive, shallow, and the other system is slow, elaborate, complex. The 'discursive nature' of self-talk refers to the idea that inner speech is essentially a dialogue between many different internalized positions. These different positions are hypothesized to be the individual athlete's beliefs, bodily reactions, and experiences which he or she represents and reacts to using language. Within this kind of model, System 1 and System 2 self-talk are hypothesized to serve different functions.

System 1 represents the immediate, emotionally charged reaction to a situation, such as when athletes automatically swear at themselves when they make a mistake. System 2 represents top-down, strategic use of self-talk whether this takes the form of motivational, instructional, or distracting self-talk. System 2 also monitors System 1 and attempts to regulate the automatic output. The dual-process perspective and the discursive perspective are compatible – according to Van Raalte et al. (2016) – because they together explain *how* we use self-talk (by communicating between different "internalized positions") and *why* (to use System 2 to control System 1 as well as our behavior).

The discursive aspect of Van Raalte et al.'s model is compatible with a Vygotskian model of self-regulation (see especially Larrain & Haye, 2012) as Vygotskian self-regulation is also hypothesized to be internalized dialogue stemming from overt dialogue with parents or care-givers. Similarly, the dual-process perspective is compatible if we think of System 2 as the self-regulating system, reacting to the automatic inner speech emerging from System 1. As System 2 is supposedly quasi-rational and amenable to further information coming from the outside, we should also envision it as the system that actually undergoes change during self-talk interventions (this would be termed 'strategic self-talk' in Latinjak et al.'s terminology). This happens for example when athletes during a self-talk intervention learn to override their negative thoughts in response to defeat and focus their inner voice on technique instead.

1.2. WHY SHOULD SELF-TALK DIFFER BETWEEN DIFFERENT TYPES OF SPORT?

The matching hypothesis (Theodorakis et al., 2000) proposes that self-talk differs depending on the type of sport. 'Matching' in this case refers to the idea that self-talk should 'match' the task at hand in terms of form and content in order to be effective. According to the original matching hypothesis, instructional self-talk should be more effective than motivational self-talk for sports depending on fine motor skills requiring precision and timing (such as dart throwing) while the reverse should hold for sports involving gross motor skills requiring strength and endurance (such as cycling). The evidence in favor of this original matching hypothesis is mixed. The systematic review by Tod, Hardy and Oliver (2011) did not find support for the matching hypothesis as they found no difference between the effects of instructional and motivational self-talk on performance on gross and fine motor skills tasks. On the other hand, a meta-analysis by Hatzigeorgiadis et al. (2011) did find support for the matching hypothesis as instructional self-talk interventions were more effective for fine motor tasks than motivational self-talk interventions were, and instructional self-talk was also found to be more effective for fine motor tasks than for gross motor tasks. More recent developments of and additions to the matching hypothesis have refined its predictions, for example suggesting that instructional self-talk may be more effective at early stages of learning (see e.g. Zourbanos et al., 2013). Indeed, Hatzigeorgiadis et al. (2011) found that task familiarity moderated the effect of self-talk on performance with the effect for novel tasks being on average larger ($d = .73$) than the effect on learned tasks ($d = .41$). Conceptualizations of the function of self-talk in sport have, as indicated above, undergone drastic developments over the last decade (see Latinjak et al., 2019, for a summary), and one further aspect that has been refined is the idea that different skill-levels and different types of sport place different demands on self-talk (see e.g. Hatzigeorgiadis, Zourbanos, Mpoumpaki, & Theodorakis, 2009). Thus, we were interested in how organic self-talk (i.e. not imposed from interventions) differed between different sports.

1.3. WHY SHOULD SELF-TALK BE RELATED TO SKILL-LEVEL IN ENDURANCE SPORT?

Only a few studies to date have directly investigated self-talk in endurance sport. This type of sport is particularly interesting from a cognitive perspective because it involves a real-world example of a challenge that requires a sustained high degree of cognitive control. Long-distance runners, cyclists, swimmers, rowers, etc. have to continuously inhibit the prepotent response (slowing down/quitting) in order to fulfill a longer-term goal (winning/completing). Performing this type of activity also offers rich opportunities for self-talk as the athletes are often alone with their thoughts for prolonged stretches of time during both training and competition. The self-talk content in endurance sport has previously been investigated in a questionnaire study on marathon runners by Van Raalte et al. (2015) and seven intervention studies (Blanchfield, Hardy, de Morree, Staiano, & Marcora, 2014; Wallace et al., 2017; Hatzigeorgiadis et al., 2018; Hamilton et al., 2007; Schüler & Langens, 2007; McCormick, Meijen, & Marcora, 2018; Barwood et al., 2015). Van Raalte et al. (2015) asked a large number of marathon runners ($N = 483$) to list their thoughts in an open-ended way and later coded the answers into categories. The authors found that 88 % of marathon runners reported engaging in self-talk while running, and that this self-talk took a variety of both motivational and instructional forms. Although their study did not explicitly associate self-talk with marathon performance, Van Raalte and colleagues did find that elite marathon runners meeting standards set by USA Track & Field engaged significantly more in associative self-talk (i.e. self-talk related to the body and running technique) than non-elite marathon runners.

The intervention studies investigating endurance sport vary widely in type and duration of intervention, the inclusion of a plausible, active control group, and the kind of physical activity investigated. For example, Blanchfield, Hardy, de Morree, Staiano, and Marcora (2014) found that a two-week motivational self-talk intervention was associated with both improved endurance performance on an exercise bike and reduced ratings of perceived exertion compared to a passive control group. The remaining laboratory-based studies found that positive (Hamilton et al., 2007) and motivational (Barwood et al., 2015) self-talk improved endurance cycling performance, including under conditions of uncomfortable heat (Wallace et al., 2017; Hatzigeorgiadis et al., 2018). Specifically, with regard to endurance sports, it is worth noting that only two intervention studies to date have taken place outside the laboratory, thus limiting the ecological validity of the findings. In these two "field studies", one found an effect of self-talk on endurance sport (Schüler & Langens, 2007), while the other did not (McCormick, Meijen, & Marcora, 2018). McCormik, Meijen, and Marcora (2018) found that runners who were trained on motivational self-talk reported finding the intervention helpful although it did not affect their performance on a 60-mile, overnight ultramarathon. Schüler and Langens (2007) found that self-talk training provided a successful buffer against the negative impact of psychological crises during a marathon race.

1.4. PRESENT QUESTIONS

The present study aimed to replicate existing findings on the prevalence and efficacy of self-talk in sports and relate these findings to cognitive science research more broadly. In addition, its goal was to explore the effects of personal and contextual factors on self-talk (Van Raalte et al., 2016) with Study 1 comparing self-talk across sport contexts (type of sport) and Study 2 exploring how personal factors (e.g., skill-level) are related to self-talk and performance.

It is often assumed in the literature that different types of sports place different demands on self-talk (see for example the matching hypothesis; Theodorakis et al., 2000), but direct comparisons of different sports, e.g. involving different levels of fine motor control, have rarely been conducted in the same study. In Study 1, we tested whether it was possible to discern the types of self-talk produced by practitioners of a sport involving a high degree of technical control (*in casu* badminton) versus a sport relying more on endurance (running). These two types of sport are also notably different in that badminton is a game while running is often a timed event. In Study 2, which dealt exclusively with long distance runners, we also tested whether self-talk was associated with marathon/half marathon running ability as well as whether participants differed in their self-talk use in high pressure versus low pressure situations. We hypothesized that high effort would be associated with abbreviated, associative self-talk and that low effort would be associated with dissociative self-talk in fuller sentences. With regard to the connection between self-talk and skill-level, there is evidence that a lower skill-level is associated with more self-talk, both in children learning a skill for the first time (e.g. Kray, Eber, & Karbach, 2008) and in adults performing difficult tasks (e.g. Emerson & Miyake, 2003). In Study 2, we therefore investigated the relationship between self-talk and skill-level as well as differences in self-talk associated with high and low effort.

In both Study 1 and Study 2, we also asked participants how often they exercised, as we hypothesized that people who exercise frequently will be more adept at using self-talk as a tool for motor control and endurance.

2. STUDY 1: METHOD

2.1. Overview

The Automatic Self-Talk Questionnaire for Sports (ASTQS; Zourbanos et al., 2009) is a questionnaire made to measure the quantity and quality of self-talk used by athletes of varying levels of activity and fitness. The questionnaire measures four positive and four negative self-talk dimensions. Positive self-talk consists of psych-up (e.g. 'come on'), confidence (e.g. 'I'm very well prepared'), anxiety-control (e.g. 'don't get upset'), and instruction (e.g. 'concentrate on what you have to do right now' while negative self-talk consists of worry (e.g. 'I'm going to lose'), disengagement (e.g. 'I can't keep going'), somatic fatigue (e.g. 'I'm tired'), and irrelevant thoughts (e.g. 'what am I doing later today?'). In Study 1, we used the ASTQS to investigate whether the quantity, quality, and perceived efficacy of athletes' self-talk varied with their preferred activity. Specifically, we hypothesized that we would find significant differences between people who engage in a gross motor endurance sport like running and people who prefer a technical sport like badminton.

2.2. Participants

We recruited participants from Danish Facebook groups dedicated to badminton and running. In total, 270 participants completed the survey (127 men and 143 women; 70 in the 18-25 age group, 55 in the 26-35 age group, 48 in the 36-45 age group, 73 in the 46-55 age group, 19 in the 56-65 age group, and 5 in the 66-75 age group). Our sample included 165 runners and 105 badminton players. The project received ethical approval from the Internal Review Board at Aarhus University.

2.3. Materials

We deployed a Danish translation of the ASTQS online via SurveyXact (https://www.surveyxact.dk/). The translation was initially conducted by the first author and validated by the second author as well as a professional English-Danish translator. There have been issues with translating the ASTQS to Spanish in the past (see Latinjak et al., 2016) and we took their concerns about specific items into account when conducting the Danish translation (e.g. changing 'concentrate on your game' to 'concentrate on your own performance' to adapt to a wider range of sports). The ASTQS originally included 40 items, consisting of examples of self-talk which the participants were asked to indicate how often they said to themselves while exercising ('Never', 'Rarely', 'Sometimes', 'Often', 'Very often'). The original study of the ASTQS (Zourbanos et al., 2009) tested both an eight-factor model and a ten-factor model with eight first-order and two second-order factors and found support for both structures. This was later confirmed in both studies on sport (Zourbanos et al., 2011; Zourbanos, Hatzigeorgiadis, Tsiakaras, Chroni, & Theodorakis, 2010) and physical education (Zourbanos, Papaioannou, Argyropoulou, & Hatzigeorgiadis, 2014). We added four questions about the specific sport, activity level, perceived self-talk frequency, and perceived self-talk efficacy. Participants were introduced to the questionnaire in the following way: 'The following questionnaire contains sentences describing the thoughts of athletes. Base your answers on your latest competition or training and use the scale to indicate which thoughts you normally experience or use on purpose while exercising.'

2.4. Machine learning models

Since the factors that emerge from the ASTQS are heavily correlated, we could not use them for linear mixed model regression analyses as predictors. Instead, we chose to use machine learning models to predict sport type and exercise frequency from all the questionnaire items. For predicting sport type and exercise frequency from the questionnaire items, we fit a classification and a regression model respectively using the 'glmnet' (Friedman, Hastie, & Tibshirani, 2010) and 'caret' (Kuhn, 2020) packages in R version 3.6.2 (R Core Team, 2019). The 'glmnet' method fits a generalized linear model via penalized maximum likelihood and thus avoids multicollinearity of predictors which would be an issue for regular linear mixed models. We used repeated k-fold cross-validation in all the models to get stable estimates of the models' predictive performance.

3. STUDY 1: RESULTS

3.1. Questionnaire reliability

We calculated the internal consistency (Cronbach's alpha) of the entire questionnaire using the following formula

$$\alpha = \frac{p}{p-1}\left(1 - \frac{\Sigma_{i=1}^{p}\sigma_{y_i}^2}{\sigma_x^2}\right)$$

where p is the number of items, σ_x^2 is the variance of the observed total test scores, and $\sigma_{y_i}^2$ is the variance of the ith item. The questionnaire had a Cronbach's alpha of 0.889, indicating a good internal consistency.

3.2. Self-talk frequency and self-talk efficacy

See Table 1 for an overview of answers split into runners and badminton players and Figure 1 for visualizations of the responses.

Table 1. *Self-talk frequency and self-talk efficacy by sport type.*

		Runners (N = 165)	**Badminton players (N = 105)**
Self-talk frequency	**Never**	22 (13.33 %)	3 (2.86 %)
	Rarely	31 (18.79 %)	6 (5.71 %)
	Sometimes	40 (24.24 %)	32 (30.48 %)
	Often	53 (32.12 %)	43 (40.95 %)
	Very often	19 (11.52 %)	21 (20 %)
		Runners (N = 143)	**Badminton players (N = 102)**
Self-talk efficacy	**Positive**	62 (43.36 %)	43 (42.16 %)
	Negative	2 (1.40 %)	3 (2.94 %)
	It depends	37 (25.87 %)	44 (43.14 %)
	None	42 (29.37 %)	12 (11.76 %)

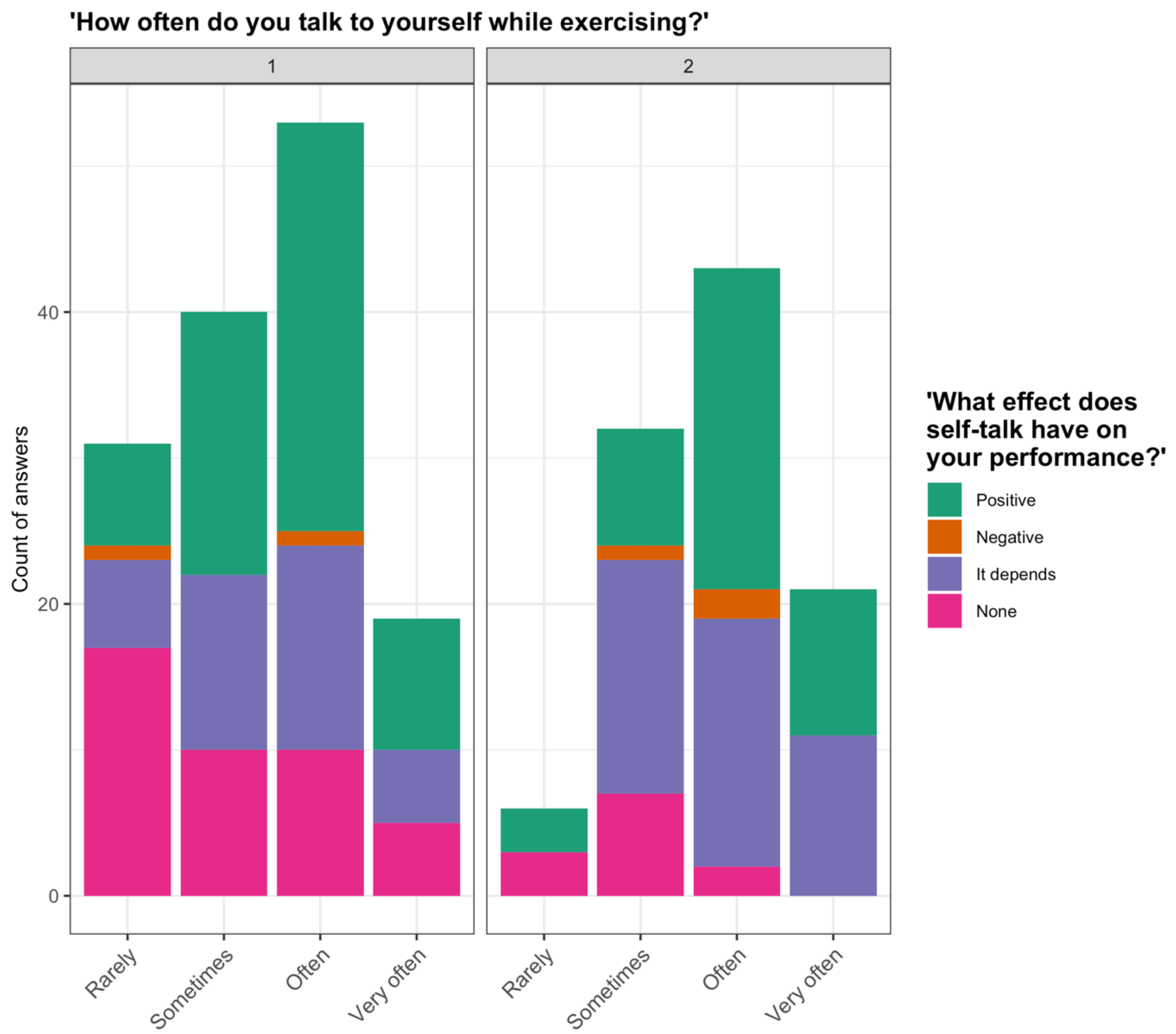

Figure 1. *Self-talk frequency and self-talk efficacy in our sample of runners (1) and badminton players (2).*

3.3. Machine learning models

3.3.1. Sport type

We fitted three classification models with the 'glmnet' algorithm on the entire data set: one model of age, gender, and exercise frequency predicting sport type, one model of the questionnaire items predicting sport type, and one model with both the questionnaire items and age, gender, and exercise frequency predicting sport type (see Table 2 for all the model fit statistics for the three models). We did this instead of training the model on a training set and testing it on a test set because the random split was too unstable given the size of the entire data set. As there were slightly more runners than badminton players in the current sample, we also down-sampled the training set to alleviate class imbalances. The model centered and scaled the data and ran different versions of the tuning parameters α and λ 20 times each with 5-fold cross-validation and 100 repeats. α denotes the optimal mix between lasso and ridge regression (in this case nearly equal amounts of both as α ranges from 0, pure ridge regression, to 1, pure lasso regression) and λ is a measure of the penalty associated with the multicollinearity of the predictors. A 5-fold cross-validation means that the model splits the data into five subfolds, trains on four of these, and tests its predictions on the fifth subfold. See Figure 2 for an illustration of which questionnaire items predicted sport type. Accuracy was used to select the optimal model using the largest value.

Table 2. *The best tune statistics α and λ for each of the three classification models as well as means and standard deviations of accuracy and ϰ on the fifth subfold. ϰ is an adjusted measure of accuracy given class imbalances and is calculated by (observed accuracy - expected accuracy)/(1 - expected accuracy). All models were run with random seed 100.*

	α	**λ**	**ϰ (SD)**	**Accuracy (SD)**
Demographics only model	0.81	0.11	0.50 (0.11)	77.15 % (4.69 %)
Questions only model	0.1	0.13	0.78 (0.08)	89.08 % (3.97 %)
Full model	0.1	0.05	0.77 (0.08)	88.93 % (3.96 %)

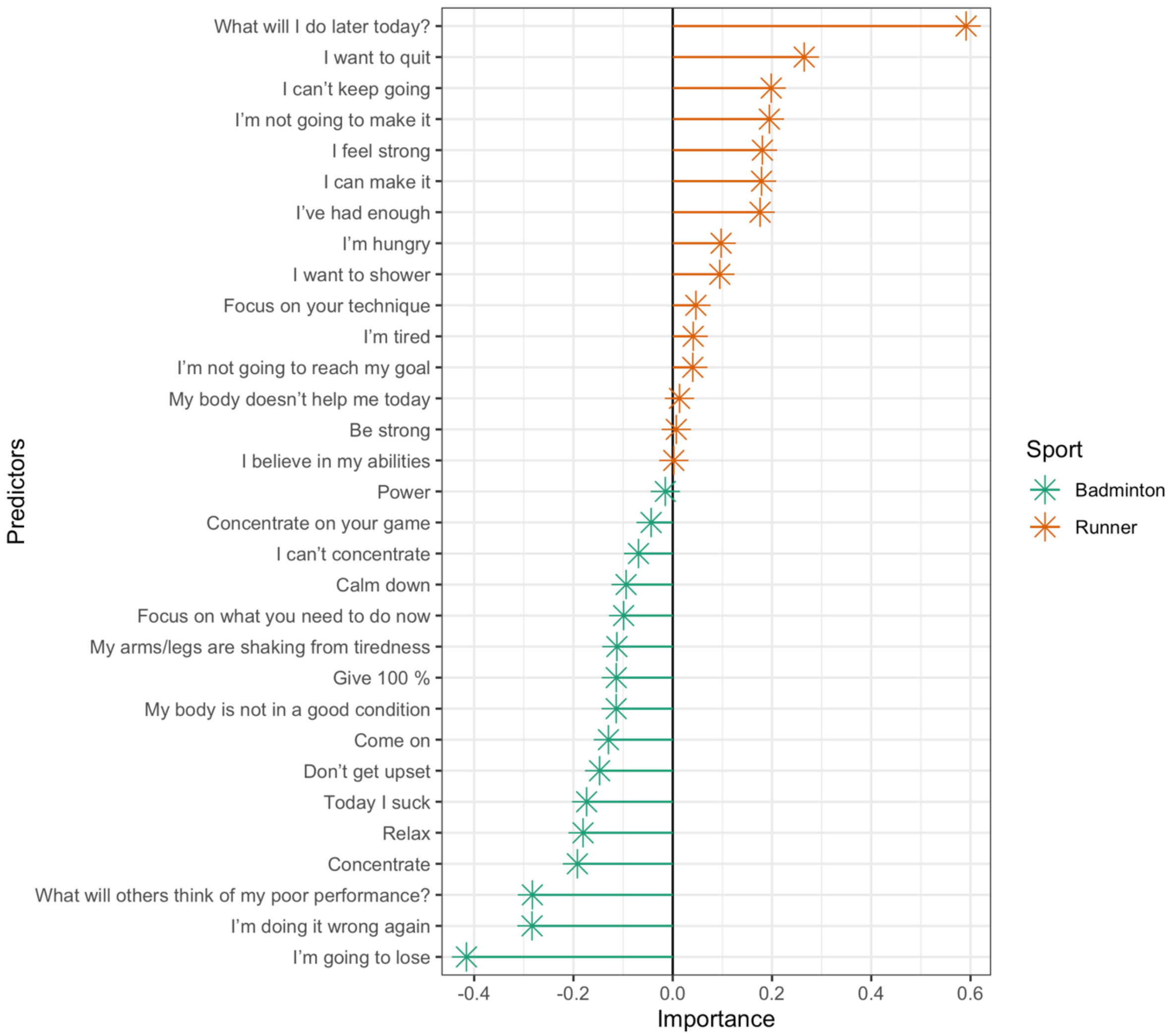

Figure 2. *An illustration of which individual questions could be used to predict sport type. The x axis shows regression coefficients of the individual questions while the y axis shows the questions themselves. High endorsement of green items made it more likely that the individual was classified as a badminton player while high endorsement of orange items made it more likely that the individual was classified as a runner.*

3.3.2. Exercise frequency

We fitted a regression model again with the 'glmnet' algorithm using the entire data set. Apart from the questionnaire items, we again also included gender and age as predictors. The model centered and scaled the data and ran different versions of the tuning parameters α and λ 20 times each with 5-fold cross-validation and 100 repeats. The final values used for the model were α = 1 and λ = 0.05. Across the 100 repeats, the model achieved a mean R^2 of 12.83 % (SD = 7.98 %), a mean MAE of 0.68 (SD = 0.05), and a mean RMSE of 0.85 (SD = 0.06). See Figure 3 for an illustration of which specific questionnaire items were important for predicting exercise frequency.

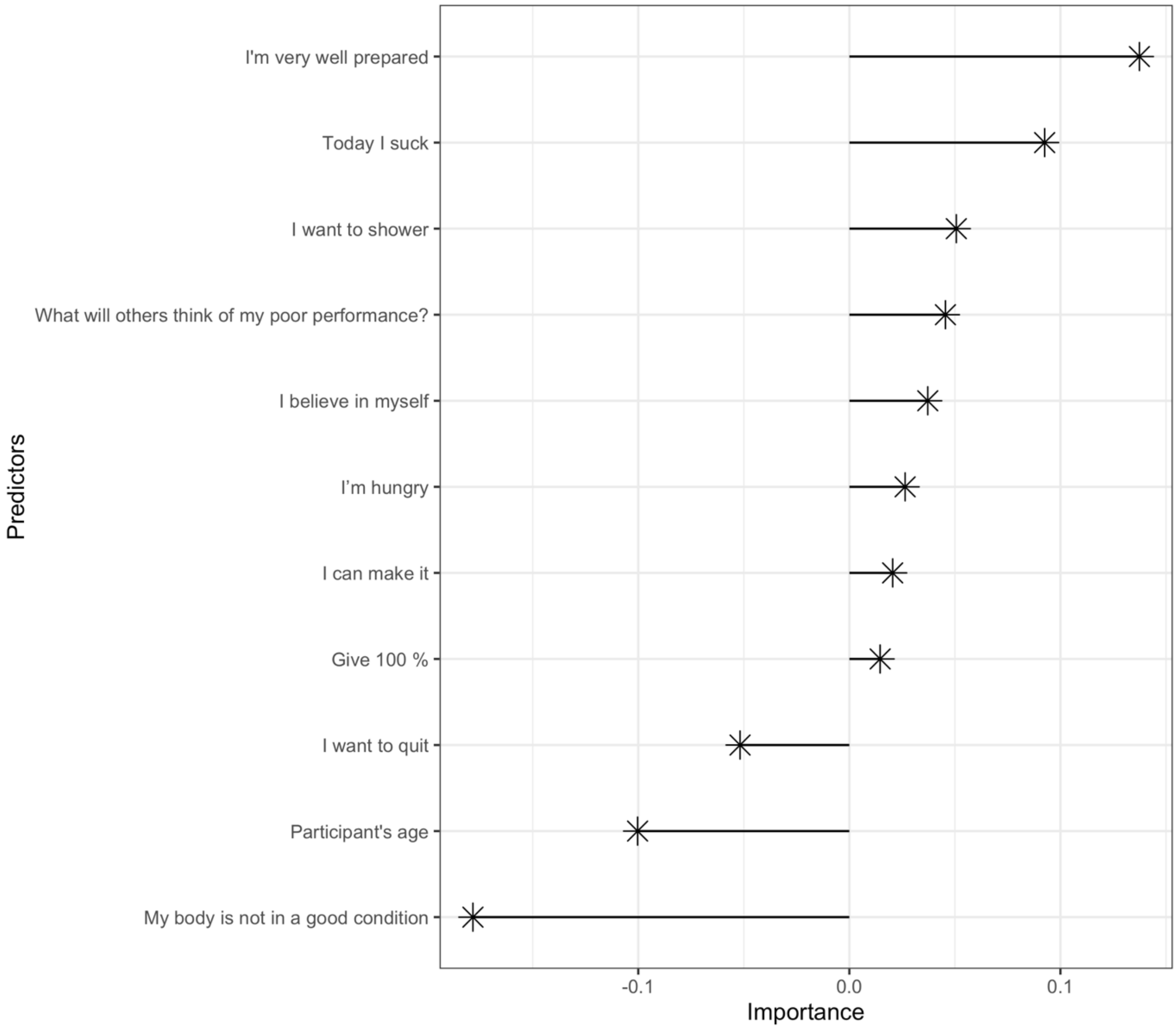

Figure 3. *Regression coefficients of the most important questionnaire items (>0) for predicting exercise frequency. Positive coefficients indicate positive correlation while negative coefficients indicate negative correlation.*

3.4. Interim discussion

We replicated the findings that self-talk is reported to be widely used in sports with approximately 70-90 % of runners and badminton players reporting engaging in self-talk, sometimes, often or very often (Table 1). In addition to this, we documented important differences in the content of self-talk exhibited by practitioners of two different types of sport. According to our machine learning models, runners' self-talk was characterized by being more prone to disengagement and defeatism while badminton players' self-talk was more characterized by worry (e.g. 'I'm doing it wrong again') and anxiety-control (e.g. 'Don't get upset'). The results from the model predicting exercise frequency provided evidence that there is a reliable connection between how people talk to themselves and their level of fitness. Especially the most negatively predictive item ('My body is not in a good condition') and the most positively predictive item ('I'm very well prepared') provide good coherence checks for the analyses (Figure 3).

These results implicate that there are qualitative differences between self-talk during a sport like badminton which is a technical, (sometimes) team-based game and a sport like running which is more solitary, often timed, and relying on gross motor movements. The finding that runners are more prone to disengagement (Figure 2) underlines the importance of being able to control your inner voice when you are running long distances with much opportunity for self-doubt and defeatism.

Criticism of the ASTQS has been brought forward, for example from Thibodeaux and Winsler (2018) who observed youth tennis athletes' overt self-talk and compared it with their endorsement of items on the ASTQS. A lack of clear correspondence was observed. This criticism applies less to our study for two main reasons. First, we do not see reason to believe that external and internal self-talk should be identical – for instance, previous research has shown that internal self-talk is much more frequent than external self-talk (Brinthaupt, Boling, & Wilson, 2000). In fact, we expect external self-talk to be mostly System 1 and internal self-talk to be mostly System 2 (van Raalte et al., 2016). Second, Thibodeaux and Winsler (2018) reported that they were unable to code 49 % of the athletes' overt self-talk during matches, meaning that the lack of correlation between observed and reported self-talk could be due to methodological challenges. Nevertheless, in the light of these concerns with the ASTQS and our interest in topics outside its scope, we decided to construct a new questionnaire for Study 2.

4. STUDY 2: METHOD

4.1. Overview

For Study 2, we wanted to explore how self-talk differed in terms of form and content in high intensity versus low intensity situations. Our new questionnaire queried participants' self-talk in high versus low effort situations (in both training and competition) and asked about positive content, negative content, other-athletes focused content, and task-irrelevant thoughts. In terms of the form of self-talk, the questionnaire asked about length and variety. We did not find this combination of topics in previously developed questionnaires for self-talk in sport but all appear as subcomponents of separate questionnaires. For example, the Self-Talk Use Questionnaire (Hardy, Hall, & Hardy, 2005) measures linguistic form (single words, phrases, full sentences) but not other-athletes focus or task-irrelevant thoughts while the ASTQS measures other-athletes focus and task-irrelevant thoughts but not linguistic form. We also asked participants to provide their personal best marathon and/or half marathon time. See Appendix A2 for the questionnaire used in Study 2.

4.2. Participants

We recruited participants from Danish Facebook groups dedicated to marathon running. In total, 293 participants completed the questionnaire. Two of them were excluded because their marathon or half marathon time was not decipherable. The remaining 291 participants were 111 men, 179 women, and one non-binary (12 in the 18-25 age group, 45 in the 26-35 age group, 112 in the 36-45 age group, 102 in the 46-55 age group, and 20 in the 56-66 age group). All except three reported exercising at least a few times a week. The project received ethical approval from the Internal

Review Board at Aarhus University. All except 55 participants provided their best marathon time (*M* = 245 minutes, *SD* = 42.7 minutes) while all except 15 participants provided their best half marathon time (*M* = 112.7 minutes, *SD* = 18.9).

4.3. Materials

We deployed the questionnaire online via SurveyXact (https://www.surveyxact.dk/). Participants were asked to indicate how often ('Never', 'Rarely', 'Sometimes', 'Often', 'Very often') they use a particular kind of self-talk (positive, negative, task-irrelevant, or concerning other people) under high-pressure and low-pressure conditions. They could also answer 'I don't talk to myself'. High-pressure questions were initiated with the sentence fragment 'When I push myself while running…' and Low-pressure questions were initiated with the sentence fragment 'When I run without pushing myself…'. Participants were also asked what form their inner speech takes in terms of variation and length. Again, they had the option to answer 'I don't talk to myself'. In total, there were 20 questions about self-talk specifics. A machine learning model was not suitable to predict the difference between high and low intensity questions as the high intensity/low intensity paired structure of the items would be lost. Instead, we tested this difference with Wilcoxon's paired samples tests as normality assumptions were not met.

4.4. Machine learning models

Once again, the questionnaire items were too heavily correlated for use in linear mixed model regression analyses as predictors. Instead, we chose to use machine learning models to predict marathon and half marathon proficiency from all the questionnaire items. As in Study 1, we fitted a regression model using the 'glmnet' (Friedman, Hastie, & Tibshirani, 2010) and 'caret' (Kuhn, 2020) packages in R version 3.6.2 (R Core Team, 2019). The 'glmnet' method fits a generalized linear model via penalized maximum likelihood and thus avoids multicollinearity of predictors which would be an issue for regular linear mixed models.

5. STUDY 2: RESULTS

5.1. Questionnaire reliability

The questionnaire we used in Study 2 only had a Cronbach's alpha of 0.601 (see Study 1 for how it was calculated), indicating poor internal consistency, i.e. that the items are unlikely to measure only one underlying concept. This is not surprising given that we designed the questionnaire to measure self-talk under high and low pressure conditions and thus the questionnaire should not be unidimensional. There were not enough items to calculate Cronbach's alpha for high and low pressure separately, so in the following we will conduct analyses with individual questions.

5.2. Self-talk frequency and self-talk efficacy

Of the participants, 91.75 % (267 participants) reported talking to themselves while running 'Sometimes', 'Often', or 'Very often' (compared to approx. 70 % of runners in Study 1). In terms of self-talk efficacy, 63.57 % (185 participants) reported that talking to themselves usually had a positive effect on their performance while 25.77 % (75 participants) reported that it sometimes had a positive effect and sometimes a negative effect. In Study 1, 43.36 % of runners reported a positive effect of self-talk on performance while 25.87 % reported that it sometimes had a positive and sometimes negative effect. Only one participant in the present study reported self-talk usually having a negative effect on performance. In this sample, 10.31 % (30 participants) reported self-talk having no effect on their performance (compared to approx. 30 % of runners in Study 1). See Figure 4 for a visualization of the self-talk efficacy and self-talk frequency data.

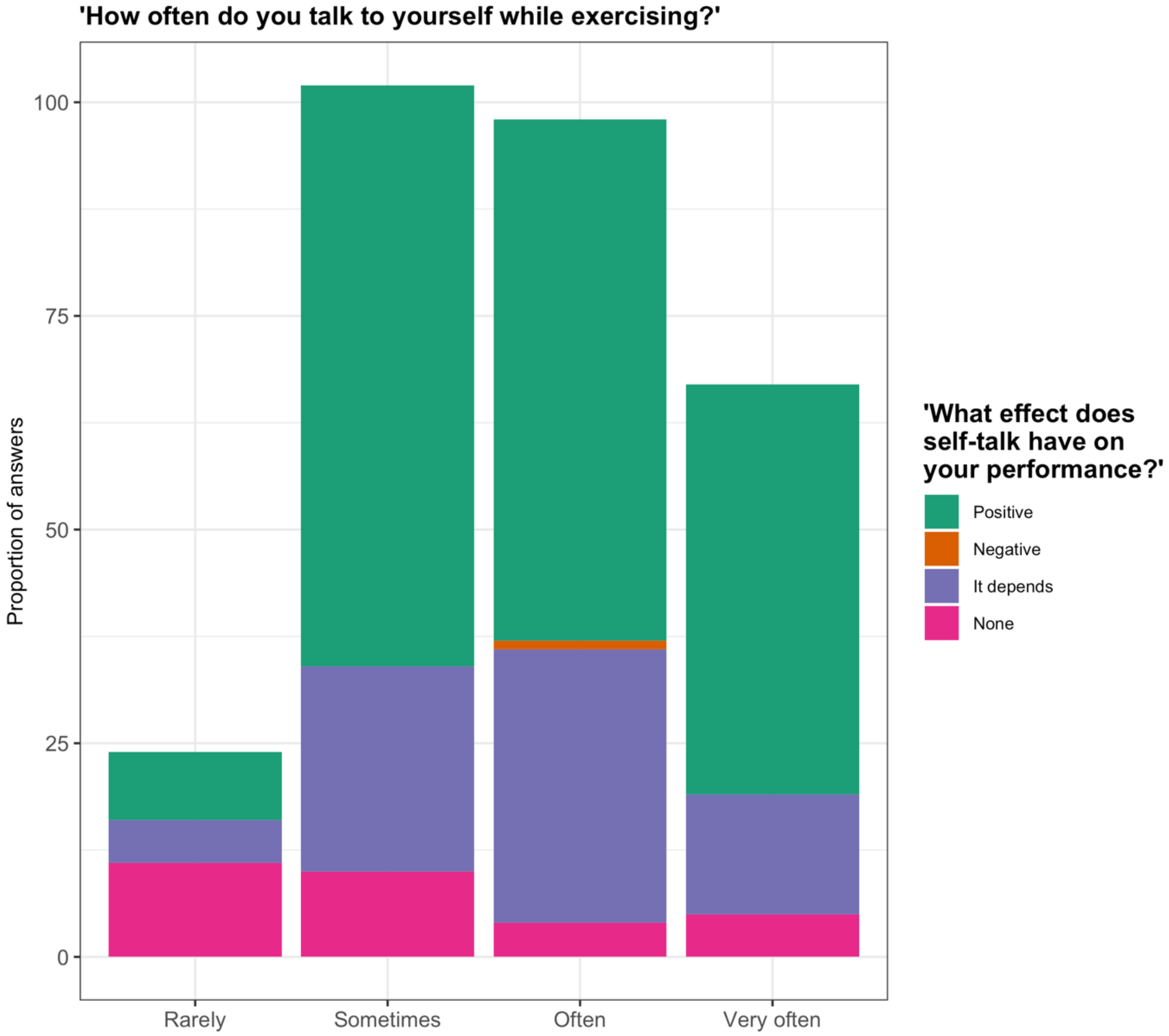

Figure 4. *Visualisation of the marathon runners' answer to self-talk frequency and self-talk efficacy questions.*

5.3. Predictor: High intensity versus low intensity

To test whether participants differed in their answers to high intensity and low intensity questions, we conducted 10 Wilcoxon paired samples tests (since normality assumptions were not met), the results of which can be seen in Table 3. Each pair included the same question asked for high intensity and low intensity. It appeared that self-talk under high intensity conditions tended to be more strongly valenced (both positively and negatively), less about other things than the race, and more condensed in terms of both form and content. See Figure 5 for a visual representation of the difference in answers to questions about high intensity versus low intensity.

Table 3. *Wilcoxon paired samples tests of the difference between answers to questions about high pressure and low pressure running. Asterisks indicate statistical significance at a Bonferroni-corrected level (p < .005).*

Question	Abbreviated name (see Figure 5)	High intensity (mode with mean in paren-theses)	Low intensity (mode with mean in paren-theses)	Wilcoxon paired samples test
… I talk down to myself.	*condescend*	Never (1.84)	Never (1.57)	p < .001*
… I say encour-aging things.	*encourage*	Often (3.67)	Sometimes (2.62)	p < .001*
… I talk in long sentences.	*long*	Rarely (2.11)	Sometimes (2.62)	p < .001*
… I don't talk to myself (content).	*noTalkContent*	Rarely (2.12)	Rarely (2.31)	p = .002*
… I don't talk to myself (form).	*noTalkForm*	Rarely (2.14)	Rarely (2.20)	p = .22
… I think about what others think.	*othersFocus*	Rarely (2.17)	Never (2.16)	p = .976
… I repeat the same words over and over.	*repetition*	Sometimes (3.20)	Rarely (2.28)	p < .001*

… I talk in short sentences.	*short*	Often (3.66)	Sometimes (2.92)	p < .001*
… I talk to myself about other things than the race.	*taskIrr*	Sometimes (3.01)	Sometimes (3.41)	p < .001*
… I talk about a variety of things.	*variety*	Sometimes (2.70)	Often (3.31)	p < .001*

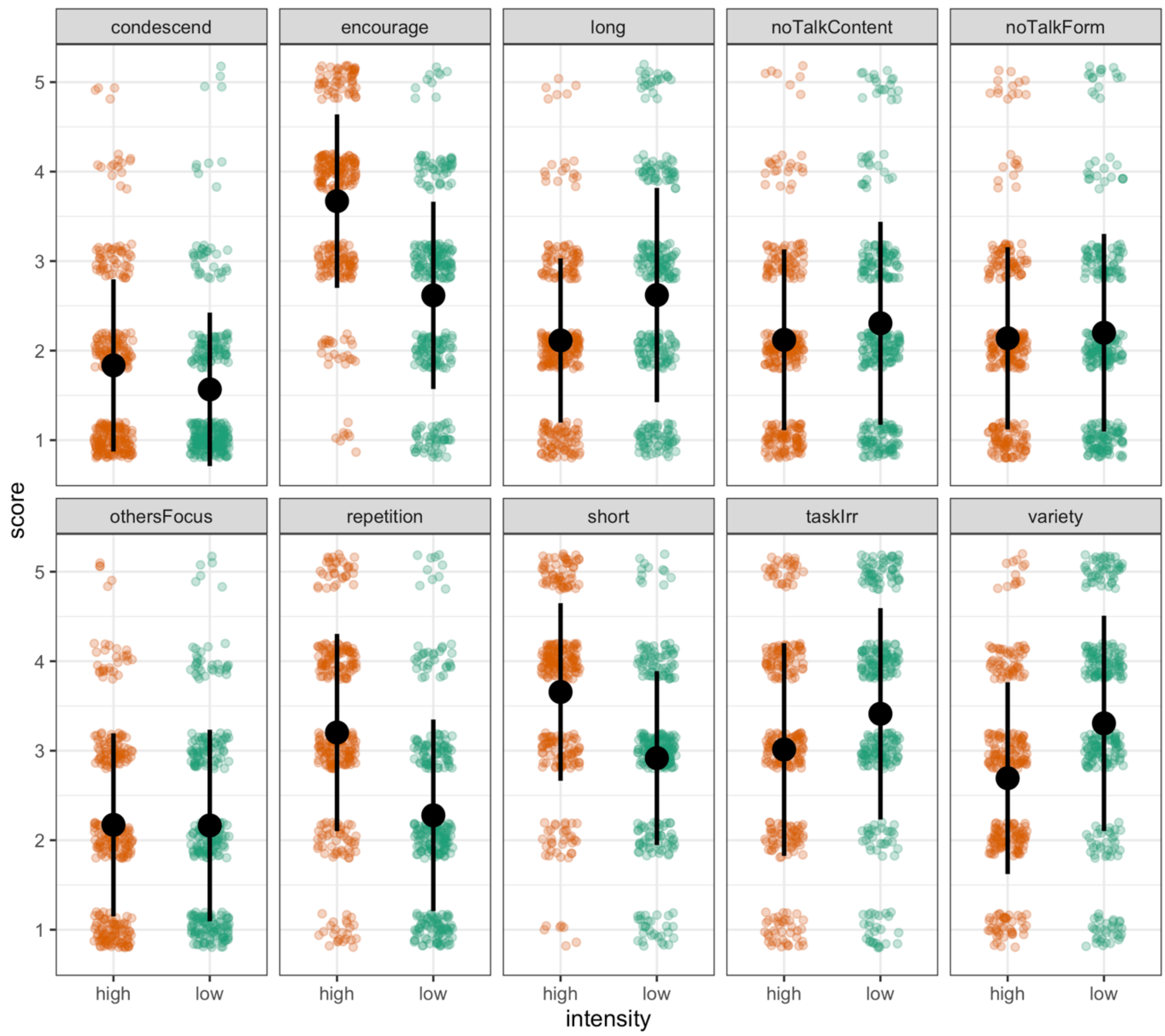

Figure 5. *Illustration of the distributions in the way participants answered the questions also presented in Table 3 (paired for high intensity (orange) and low intensity (green)). Degree of endorsement of the questionnaire statements is on the y axis, ranging from 1 ('Never') to 5 ('Very often') on a discrete scale. The full questions matched with the abbreviated names can be seen in Table 3.*

5.4. Machine learning models

5.4.1. Variance explained by demographics and questionnaire items

Marathon and half marathon proficiency were operationalized by using each participant's self-reported personal record in minutes. Given that running proficiency is likely to be influenced not only by self-talk but also by a range of other factors (such as exercise frequency, experience, age, and gender), we included exercise frequency, age, and gender as predictors in the models in addition to the questionnaire items. To estimate the degree to which running proficiency could be predicted by self-talk, we compared the variance explained by models including age, gender, exercise, and self-talk items to models only including age, gender, and exercise. In total, we built six 'glmnet' predictive models: two for half marathon and marathon predicted by age, gender, and exercise frequency, two for half marathon and marathon predicted by age, gender, exercise frequency, and all self-talk items, and two for half marathon and marathon predicted by the questionnaire items only. For all the models, we ran 5-fold cross-validation with 100 repeats. A 5-fold cross-validation means that the model splits the data into five subfolds, trains on four of these, and tests its predictions on the fifth subfold. We did this instead of splitting the data into a training set and a test set because the random split would be too unstable given the size of our complete data set. All models centered and scaled the data and ran different versions of the tuning parameters α and λ 20 times each. In all cases, the optimal model was chosen based on the highest value of R^2 (amount of variance explained). See Table 4 for a complete set of model tuning parameters and fit statistics.

Table 4. *The best tune statistics* α *and* λ *for each of the six regression models as well as means and standard deviations of RMSE (Root Mean Squared Error),* R^2*, and MAE (Mean Absolute Error) on the test subfold across the 100 repeats. All models were run with random seed 100.*

	α	**λ**	**RMSE (SD)**	**MAE (SD)**	**R^2 (SD)**
Half marathon					
Demographics-only model	0.1	0.45	16.93 (1.35)	13.53 (1.00)	20.44 % (9.62 %)
Questionnaire-only model	0.1	6.25	18.15 (1.57)	14.40 (0.91)	9.08 % (7.33 %)
Full model	0.1	4.07	16.91 (1.47)	13.37 (0.98)	20.73 % (8.84 %)
Marathon					
Demographics-only model	1	1.21	40.40 (3.26)	32.44 (2.30)	12.19 % (7.89 %)
Questionnaire-only model	0.19	17.10	40.96 (3.49)	32.80 (2.25)	9.67 % (7.08 %)
Full model	1	2.96	39.71 (3.53)	31.55 (2.48)	14.77 % (8.02 %)

5.4.2. Which questionnaire items predict running performance?

As is evident from Table 4, the questionnaire items do not seem to explain much variance above and beyond that explained by age, gender, and exercise frequency, especially for marathons. We see this from the fact that the demographics-only models explain almost as much variance as the full models. However, the models predicting half marathon and marathon time using *only* the questionnaire items also explained a reasonable amount of variance – thus, there must be shared variance between the questionnaire items and age, gender, and exercise frequency. To assess the questionnaire items' predictive power on their own over and beyond that which could be explained by the demographic variables, we built two additional regular linear regression models with the questionnaire items predicting the residuals from two demographics-only models (i.e. the unexplained variance). The half marathon model explained a significant amount of variance in the data ($F(20, 247) = 2.05$; Adjusted $R^2 = 0.07$; $p = .006$), and so did the marathon model ($F(20, 207) = 1.85$; Adjusted $R^2 = 0.07$; $p = .018$). Because the questionnaire items were likely to be correlated, we could not assess their individual predictive power with these ordinary linear regression models. Instead, we built two 'glmnet' machine learning models with the questionnaire items predicting the residuals from the demographics-only model. These models centered and scaled the data and ran different versions of the tuning parameters α and λ 20 times each. As with the previous models, we used 5-fold cross-validation repeated 100 times. These two models explained 4.42 % (SD = 4.59) of the residual variance in half marathon performance and 7.19 % (SD = 6.16) of the residual variance in marathon performance. See Figure 6 for an illustration of the most important questionnaire items predicting residual variance in half marathon and marathon time with the effects of age, gender, and exercise frequency removed.

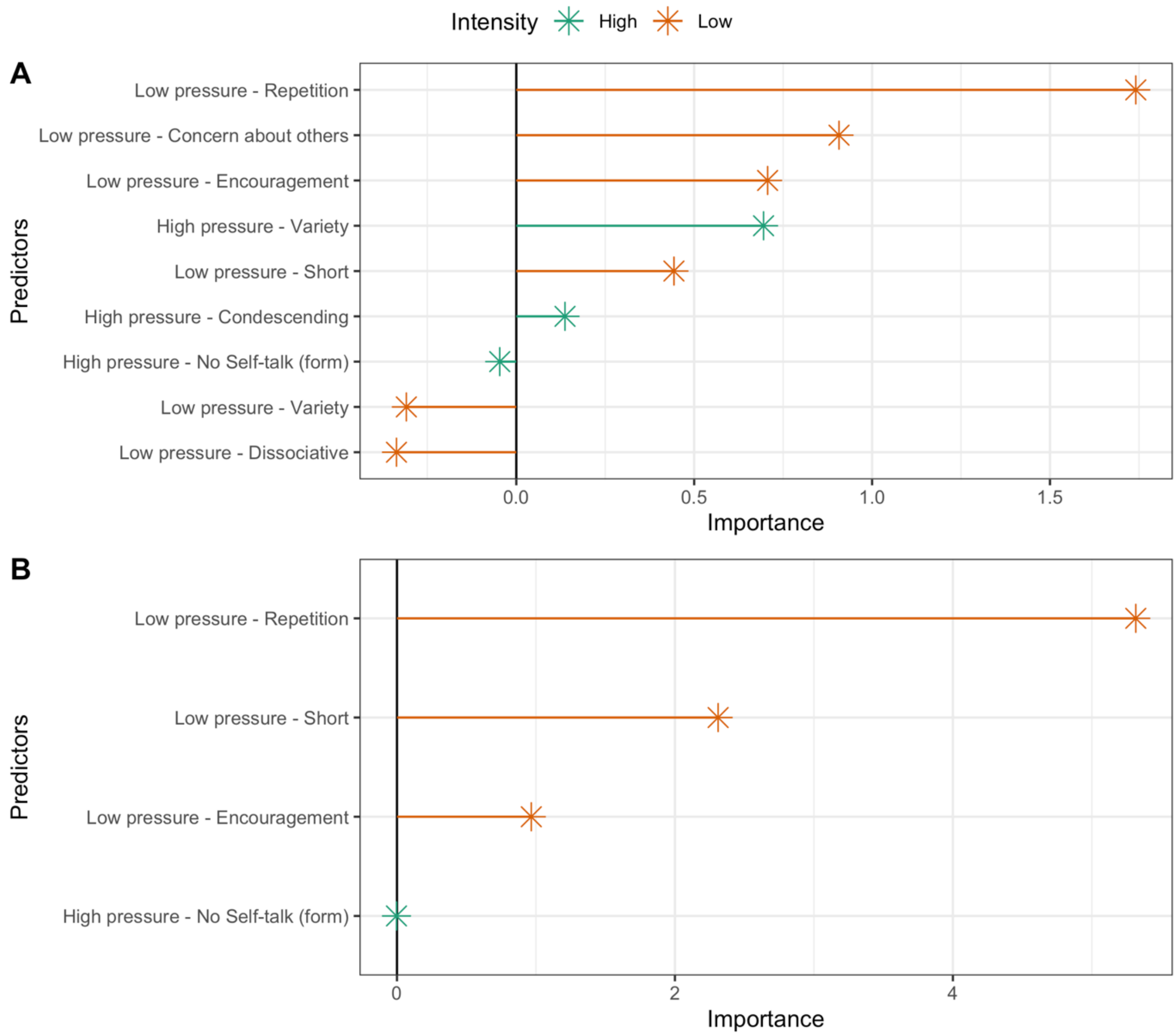

Figure 6. *Regression coefficients of the most important questionnaire items predicting the residual variance in half marathon time (A) and marathon time (B). Positive coefficients indicate increase in running time (i.e. worse performance) while negative coefficients indicate decrease in running time (i.e. improved performance).*

5.5. Summary

In Study 2, we replicated the finding from Study 1 that self-talk is extremely prevalent in sport – especially endurance sports like marathon and half marathon running – and that most athletes experience that talking to themselves improves their performance. Marathon runners notably said both that they talk to themselves more and believe in the efficacy of talking to themselves more than a more mixed group of runners do (compare self-talk frequency in Study 1 and 2). Further, we found that self-talk in our sample differed between high intensity and low intensity situations with self-talk in high pressure situations being characterized as more strongly valenced (both in the positive and negative direction), shorter, and with more repetitions than self-talk in low pressure situations. Our machine learning models were able to predict a large amount of variance in half marathon and marathon performance when we included both the questionnaire items and age, gender, and exercise frequency. When we examined the individual questionnaire items more carefully while excluding effects of age, gender, and exercise frequency, we found that especially items concerning positive, short, and repetitive self-talk under low pressure were associated with worse running performance for both marathon and half marathon runners.

6. DISCUSSION

Our results from both Study 1 and Study 2 corroborated results from the existing literature suggesting that athletes talk to themselves while exercising and that they generally believe it helps them perform better. Using machine learning models, we also found some indication that you can predict both people's skill-level and type of sport from the content of their self-talk. This provides support for the idea that self-talk actually matters and is not just an epiphenomenon of mental life. Our results from Study 2 indicate that self-talk differs depending on high pressure and low pressure conditions, again confirming existing findings from both sports psychology and cognitive psychology more broadly that the inner voice is invoked in a qualitatively different manner when we face challenges (Hatzigeorgiadis et al., 2011; Hardy, Oliver, & Tod, 2009; Kray, Eber, & Karbach, 2008; Emerson & Miyake, 2003). The finding that marathon runners reported talking to themselves in short sentences with much repetition under high pressure also suggests that the cognitive resources available for self-regulation under such conditions may be limited compared to less intense situations.

6.1. Self-talk as tool use

Like previous literature, we found that self-talk appears to differ depending on type of sport and high pressure versus low pressure situations. As in Van Raalte et al. (2015)'s study on marathon runners, we found significant differences between the self-talk of competent and of less competent marathon runners. The only type of self-talk that differed significantly (between elite and non-elite) in Van Raalte et al.'s study was so-called 'associative' self-talk with elite marathon runners engaging more in this type. Associative self-talk relates to sensations of the body, pace, stride length, and posture – what one would perhaps in other sports term 'technique' or 'instructional self-talk'. The most similar item in our questionnaire (although in the opposite direction) was 'I talk to myself about things other than the race'. The low intensity answers to this item correlated negatively with half marathon time, indicating that participants who engage in dissociative self-talk while not pushing themselves have better half marathon personal records. For both marathons and half marathons, participants who endorsed short, repetitive, and encouraging self-talk when not pushing themselves had slower running times. We interpret this as indicating that they needed to use their self-talk strategically even during less arduous periods of a marathon or half marathon, and more generally that self-talk is deployed when people face novel or challenging situations. This is consistent with previous findings from both sport psychology (Hatzigeorgiadis et al., 2011; Hardy, Oliver, & Tod, 2009), cognitive psychology, and developmental studies, where children are found to be more dependent on self-talk than adults (e.g. Kray, Eber, & Karbach, 2008). Our findings are also consistent with studies showing that the detrimental effect of concurrent articulatory suppression depends on how practiced the primary task is (e.g. Emerson & Miyake, 2003). In particular, our results fit with more recent additions of the matching hypothesis (Zourbanos et al., 2013), according to which instructional self-talk should be more effective for novel tasks than for learned tasks, and motivational self-talk should be more effective for learned than novel tasks. If we think about strategic self-talk as a tool for cognitive control that is deployed when task demands necessitate it, it makes sense that you should need to use this tool less the better you are. It also yields a predictable hypothesis: Marathon runners should employ more strategic and less digressive self-talk towards the end of a run when fatigue is imminent and more control is needed to keep going, compared to the beginning of the race, where energy reserves are high. More research is needed to test this hypothesis.

6.2. Limitations of the present study

To our knowledge, this is the first study to use machine learning to analyze data in this field of research, an approach that of course both has advantages and disadvantages. The main advantage in the present paper was that using machine learning allowed us to build interpretable models with many correlated predictors. The main disadvantage of using machine learning for psychology in general is that our data sets are rarely large enough, meaning that in practical terms it will mostly be useful as a method for questionnaire studies. One problem with the present investigation is that people are not always accurate in their introspective reports, especially retrospectively and removed from the situation in question (Ericsson & Simon, 1980). In a similar vein, studies often find that people are bad at assessing what has an effect on their actions and decisions and what does not (see Nisbett & Wilson, 1977, for a classic study). Self-reported measures of self-talk should therefore be assessed critically. However, given that our results were in line with previous findings, a more consistent pattern seems to be emerging. A general problem with questionnaire studies such as the current one is that they assume that participants literally talk to themselves – the way the questions are phrased might lead participants to endorse self-talk that they do not in fact engage in. For example, if they feel they can recognize a non-verbal expression of the quoted questionnaire item, they might say they often experience the sensation even if they do not experience the literal verbal expression of it. 'I want to shower', as one of the ASTQS items reads, can be a distracting thought – you do not have to have this sentence verbatim in your head to be distracted by it, bodily sensations may be sufficient.

6.3. Future directions

We see two primary avenues for future research emerging from the present study: First, future studies should explore the specific sport- and skill-based differences in how people talk to themselves, as well as whether there are performance advantages to tailoring your self-talk. This avenue has the potential to test the idea that self-talk is a tool for self-control that should be used in a way that is appropriate to the demands of the circumstances (here in terms of technique) and might not be effective otherwise. It also remains to be seen whether the association between self-talk content and skill-level stems from marathon runners' goal-directed or undirected self-talk (Latinjak et al., 2014). The items of the questionnaire used in Study 2 are agnostic with regard to whether athletes use the items actively in a goal-directed or spontaneous way. Second, it would be interesting to go beyond the correlational nature of questionnaire studies and combine the ecological validity of assessing people performing their sport in their natural environment with the experimental control of laboratory-based studies, e.g. by using methods from cognitive science already in use to test the function and efficacy of inner speech (see Alderson-Day & Fernyhough, 2015, for a review). For the use of self-talk in sport, we could for example have people run, cycle, or row intervals while performing mental distraction tasks to see if there is an effect on their performance. If you have to talk to yourself to control your physical performance, you should perform worse on verbal distraction trials compared to nonverbal distraction trials. If self-talk is less necessary for experts than for novices, we would also expect to see an interaction between general fitness level and interference task in this case.

7. CONCLUSION

The present study replicated existing findings on the content, frequency, and function of self-talk in sports. We were able to use answers to a self-talk use questionnaire to predict specific sport (running versus badminton), pressure level (high versus low), and marathon running proficiency. Our findings from Study 1 suggest that self-talk in an individual, gross motor sport like running can be characterized by more disengagement compared to a team-based, more technically demanding sport like badminton which in turn is characterized by worry and anxiety-control. Our findings from Study 2 suggest that self-talk in high pressure situations is characterized by more condensed form and content, and simultaneously more positive and more negative compared to low pressure situations. Further, we found that participants engaging in condensed, encouraging, and repetitive self-talk in low intensity conditions had slower marathon and half marathon times. Taken together, these results indicate 1) that self-talk does serve specific, adaptive functions, and 2) that self-talk is a cognitive tool/resource that can be strategically deployed when needed. To further investigate this, future studies should explore whether tailoring self-talk to the demands of the circumstances makes a difference in terms of its efficacy, as well as test the role of self-talk sport with experiments where the use of self-talk is directly interfered with during the sport or exercise situation, for example via a verbal interference paradigm.

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APPENDIX A

A1. Study 1

Item number	Self-talk statement
3	”I’m thirsty”
38	”Be strong”
4	“My body is not in a good condition”
22	”Come on”
35	”No stress”
5	“I’m doing it wrong again”
34	“Do your best”
8	”I’m tired”
9	”I’m not as good as the others”
26	”Power”
10	”I can’t keep going”
30	”Give 100 %”
2	”I want to quit”
14	”I’ve had enough"
7	”What will I do later today?”
31	”Calm down”
25	”Focus on your goal”
15	”I want to shower”
19	”My arms/legs are shaking from tiredness”
28	”I’m very well prepared”
21	”What will others think of my poor performance?”

23	”Relax”
24	”I believe in myself”
6	“I want to get out of here”
37	“Focus on your technique”
17	“I can’t concentrate”
27	“Don’t get upset”
20	“I’m not going to make it”
29	“Focus on what you need to do now”
11	“I’m hungry”
32	“I feel strong”
12	“Today I suck”
33	“Concentrate on your game”
18	“I think I’ll stop trying”
1	“I’m going to lose”
36	“I can make it”
39	“I believe in my abilities”
13	“I’m not going to reach my goal”
16	“My body doesn’t help me today”
40	“Concentrate”

A2. Study 2

Item number	Self-talk statement
3	When I push myself while running... - ... I say encouraging things (like 'come on!').

41	When I push myself while running... - ... I talk down to myself.
42	When I push myself while running... - ... I wonder what others are thinking about me.
43	When I push myself while running... - ... I talk to myself about all sorts of other things than running.
44	When I push myself while running... - ... I don't talk to myself.
45	When I run without pushing myself... - ... I say encouraging things (like 'come on!').
46	When I run without pushing myself... - ... I talk down to myself.
47	When I run without pushing myself... - ... I wonder what others are thinking about me.
48	When I run without pushing myself... - ... I talk to myself about all sorts of other things than running.
49	When I run without pushing myself... - ... I don't talk to myself.
50	When I push myself while running... - ... I talk in long sentences.
51	When I push myself while running... - ... I talk in short sentences.
52	When I push myself while running... - ... I repeated the same words again and again.
53	When I push myself while running... - ... I talk about a variety of things.
54	When I push myself while running... - ... I don't talk to myself.
55	When I run without pushing myself... - ... I talk in long sentences.
56	When I run without pushing myself... - ... I talk in short sentences.
57	When I run without pushing myself... - ... I repeat the same words again and again.
58	When I run without pushing myself... - ... I talk about a variety of things.

59	When I run without pushing myself... - ... I don't talk to myself.